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Electricity in Mining. THE recent meeting of the American Society of Mining Engineers and the British Iron and Steel Institute in this city offered the best of evidence of the extent to which electrical power, applied in manifold ways, is becoming necessary in the large branches of engineering industry. We publish in abstract this week some of the electrical papers read before the meetings of these two allied societies. Several of them deal with the question of the magnetic treatment of iron ores, a topic which seems to be exciting no small degree of interest among mining engineers just now. The reports made show the commendable results that can be obtained by the electromagnetic process. The two principal papers, perhaps, were those by Mr. Spaulding and Prof. Elihu Thomson, both of them dealing with subjects often presented to the public heretofore, but both of them replete with suggestiveness in the many facts and ideas brought out and the admirable treatment of the elaborate topics within a very small space. The possibilities of electric power for mining use have as yet been scarcely sounded. There are enormous regions where water power is ready and can be applied in the most direct and effective way toward furnishing electric power adequate to the full development of the mines that are on every hand. The next few years will see tremendous strides in this direction. Enough has been done already to insure as great an activity in that department of electric power as we have recently seen in electrical traction.

The Glow Worm's Secret. A RECENT fascinating research by Prof. Langley impressed upon the scientific world in the most forcible way the imperfection of our present means for obtaining luminous radiation. Mankind congratulated itself when the antiquated candle and oil lamp was replaced by the more convenient and efficient gas. It was filled with joy when gas began to give way to the still more economical and brilliant electric light; and it is something of a rude shock to be told that the pale greenish glow given out by glow worms and fireflies is, considered as a transformation of chemical energy into luminous radiation, four hundred times more efficient than a gas flame and probably almost one hundred times more efficient than an incandescent lamp. These figures, marvelous as they are, are not the result of speculative imagination but of actual, exact measurements. They are not encouraging, except as they teach the immensity of the field that remains to be explored by the inventor. Coming close behind this striking research is another, this time by Staub, a German physicist, who has turned from the methods of nature to those of art, and has been investigating the luminous efficiency of the ghostly glow that comes from a lighted Geissler tube. It need hardly be said to any one at all familiar with vacuum tubes that a considerable degree of efficiency might well be expected, for the heat given out is obviously comparatively small. The final ratio between light and total energy found, varied in different tubes and different conditions from 10 to nearly 33 per cent., a prodigious figure compared with that reached by any other method of artificial illumination. The lower limit, to be sure, is scarcely above that found in the incandescent lamp, but the higher ratio speaks for itself. It is possible to obtain about 10 per cent. of the energy bound up in coal as available electric energy. The incandescent lamp gives back as light but one-twentieth of this amount; the vacuum tube then may return nearly one-third, or give a total efficiency of almost three per cent., and yet how far behind the glow worm's magic is this, the most efficient artificial process of lighting. It at once teaches a lesson of humility to the too self-satisfied electrician and shows how immensely the resources of mankind may be increased at the hands of whoever shall penetrate the mystery of a single natural process.

Earthquakes and Electricity. THERE is perhaps no more interesting and intricate subject for investigation than the marvelous electrical and magnetic phenomena that occur about and within the surface of the earth. Marvelously complicated they are, yet prolonged study has shown the intimate connection of many of them with the electromagnetic action of the sun. Still others, however, are not at all periodic in their character, and presumably depend largely on local causes. One of these is very ably discussed by Prof. Milne in another column. Popular opinion had for many years counted electrical and magnetic disturbances as among the usual concomitants of earthquakes. This idea has a scientific foundation at least, and Prof. Milne's paper gives a considerable number of cases where earthquakes have been immediately preceded or accompanied by unusual earth currents, sudden changes in magnetic inclination, dip, and even intensity, so marked in character as to attract attention. So far as these phenomena are concerned there is nothing especially extraordinary. It is not difficult to imagine that in an intensely heterogeneous magnetized body like the earth, sudden and violent internal shocks might change the magnetic distribution even by the preliminary strains that precede the actual earthquake. Earth currents may perhaps be attributed to mere mechanical disturbance of the electrodes, or in more widely diffused effects to some energetic chemical action produced perhaps by volcanic causes. But to find the potential of the air falling sharply and becoming negative at the time of an earthquake is not to be accounted for by any direct and evident cause. The fact seems well established by Prof. Milne's own examination of the records, and in view of this even the more violent phenomena noted by some old observers may perhaps be credited. Whatever the true cause may be, there is reason to believe that it must be closely connected to the origin of atmospheric electricity itself and its connection with terrestrial magnetism. It is a beautiful example of how a casual phenomenon may be involved with the most occult operations of nature. In the many years during which the magnetic and electrical properties of the earth have been subjected to the closest scrutiny comparatively little has been done toward reaching the causes. A vast amount of information has been gained, but it is somewhat disconnected and has not yet been arrayed in any generally useful form. It lacks the magical generalization that in the hands of Prof. Ewing has cast a splendid flood of light into the darkest regions of magnetic science.

An Electric Elevated Railroad. WE are glad to learn that there is finally a reasonable prospect of an electrical elevated railway, not, unfortunately, in the metropolis which most needs rapid transit, but in that specially enterprising electrical city, Boston, which has shown itself so very ready to appreciate the advantage of modern conveniences. The Massachusetts legislature, after a long and bitter wrangle, passed a bill authorizing the West End Street Railway Company to build elevated roads, and the plan which has just been proposed is the outcome of this legislative action. It is not at all the intention of the West End Company to fill Boston with a network of elevated roads, but it proposes to use a single double track road, running over a carefully selected route, to facilitate rapid transit to every part of the city. The working plans of the company are not yet made public—if, indeed, they have been settled upon—but one thing is certain, that no such heavy and unsightly structures as the New York elevated railroads will be erected in our neighboring city. The use of small motive units rendered possible by the adoption of electricity enables the superstructure to be of a lighter and more airy character than has heretofore been attempted, without, however, decreasing in the least the carrying powers of the road. The overhead supply system will probably be abandoned—as it should be in such a case—and current will be supplied to the motors through a third rail. Transfer stations at convenient points will be provided, so that for a single fare a passenger can be transported anywhere throughout a wide range of territory. The line proposed is a trifle less than five miles in length, and the route has been laid out with special reference to the best available combination that can be made between the elevated and the surface roads. Of the economy and general efficiency of an electric elevated railroad there can be little doubt. The disadvantages of the electric surface road with the overhead construction, few as they are, will be almost entirely obviated when the roadbed is removed from the pavement and placed isolated from the hindrances of traffic, above the street. With the load so well distributed over the structure, as is practicable with frequent and light trains, the weight and cost of the construction will be very much decreased and at the same time the interference with the streets through which it runs will be vastly less than on New York roads. Aside from this, the dust and dirt and smoke and noise, which has made the Manhattan system obnoxious to everybody who comes in contact with it, will be absent, and there ought to be considerably less difficulty in getting the consent of the property owners than on any other system that has been undertaken. Success to the road, and may it be the first of a long series of electric elevated roads that shall be destined to give to American cities the effective rapid transit which their enormous growth and increasing prosperity demands.

The New Value for the Ohm. WE publish this week Mr. Glazebrook's very clever discussion of methods and results that have led to our present determination of the unit of resistance. It is an admirable summary of the later and more exact experiments beginning with that of Lord Rayleigh in 1882. The history of this particular research is a very interesting one, and the results that have now been reached must be regarded as exceedingly satisfactory. All the methods which have been used are somewhat difficult experimentally, and some of them involve so many complicated corrections as to become almost unavailable for extremely exact work. Mr. Glazebrook's paper details the eight methods which have been used in the past. Of course, aside from these most experimenters have adopted slight modifications to avoid or compensate errors. On looking over the respective formulæ it will be seen that they differ greatly in complication, and consequently in the number of constants which have to be determined. As a result of complicated computations and the amount of corrections that have to be introduced, the early work led to somewhat unsatisfactory results, so that it is probably safe to reject all measurements made more than ten years ago as comparatively inexact. The result of the later experiments has been to increase the value of the ohm by a perceptible amount, as will be readily seen by examination of the paper in detail. Of all the methods, that of Lorenz is quite certainly the least likely to involve serious errors, and that of damping is the most troublesome and difficult of manipulation, although in careful hands it has led to some good results. The value of the ohm adopted in 1884—106 centimetres of the standard mercury column—was decided upon after a considerable amount of debate. Curiously enough, it happened that none of the observers present at that Paris conference had obtained results appreciably above that figure, and in spite of the earnest protest of Sir William Thomson, who held that the proposed value was too small, it was accepted. Fortunately, there has been no official action by any of the governments on that recommendation of six years ago, so that the field is left comparatively clear for the newer and more exact results. Four years ago the British Association recommended that the ohm of the Paris conference—so-called legal ohm—should be adopted for ten years. Very luckily, too, official action on that suggestion has not been taken; so that to-day it is quite possible to take up and, by the general consensus of scientific opinion, to enforce the new ohm without unwinding an indefinite amount of governmental red tape. During the past six years, filled as they have been with every kind of electrical development, such excellent work has been done in determining the unit of resistance that to-day there is very little probability of an error as great as one-tenth of one per cent. in the final value, whereas in 1884 there was an uncertainty amounting to two or three per cent. We sincerely hope that the scientific world at large, and more especially the electricians, who are most keenly interested in exact work of this kind, will join hands and push the ohm of 1890 into practical use. Sufficient pressure can easily be brought on instrument makers to secure resistance coils adjusted to the new value, and inasmuch as it is now probably certain that further changes will be of exceedingly small amount, it is most earnestly to be hoped that the old standards will pass out of use and the new one receive the hearty endorsement it deserves.

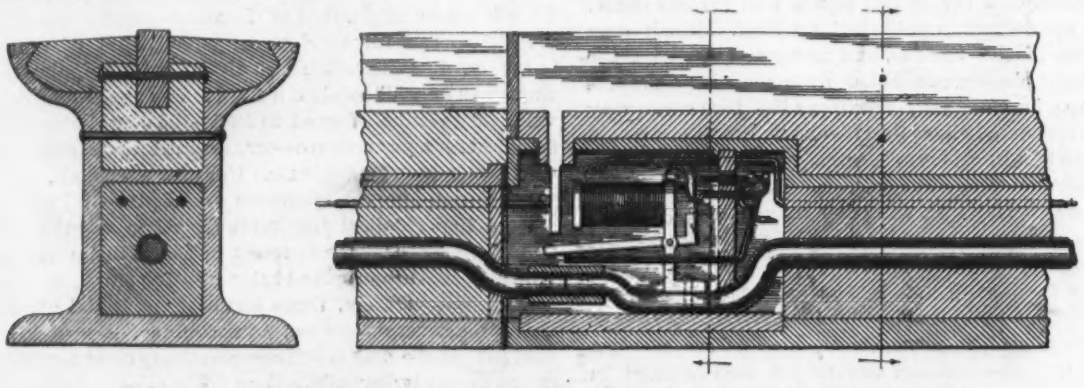
A Closed Conduit for Street Railways.

Of making conduits there is no end, and much leakage is a weariness to the flesh. The necessities of city traffic have cramped, even in this progressive country, the development of a proper system of electrical street railway service. The overhead method of supply which has proved itself to be so effective and reliable has been compelled in great measure to confine its operations to localities which really are not in such need of rapid transit as those in which overhead wiring is prohibited. As the case stands now, our cities hesitate about permitting it, more from foolish prejudice against it, stirred up in most cases by rabid organizations, than from any inherent objections to the system. Be that as it may, there has been and is a great need of some plan for supplying current to a moving motor, which shall not involve the use of a superstructure, however light, and which shall at the same time be reasonably economical and thoroughly reliable.

The storage battery has never been tried on a sufficiently large scale to give a fair idea of its commercial advantages, while the enormous weight of a battery necessary to supply the required amount of power has stood in the way of the adoption of what otherwise would be a successful solution of the difficulty. Within the past few years a number of plans have been evolved for a supply through a conduit or through rails which should be free from the objections which seem now inseparable from the slotted electrical conduit, a device which from the impracticability of preventing serious leakage has come to grief in nearly every place where it has been tried. Of these new systems several have already been described in our columns, and still others are from time to time appearing.

It is to one of this class—of which the Wheless and Lineff tramway systems are specimens—that it is the purpose of this article to refer. The general scheme of all such closed conduit or modified railway supply systems involves the use of a sectional working conductor, fed from an underground supply conductor, not continuously, but section by section, as the cars in use demand current. This end is accomplished by employing in connection with each section an electromagnetic or mechanical switch operated by the current, a magnet carried on the car or levers actuated by the car wheels. The present system has been recently patented by Mr. C. K. Harding, and utilizes in a manner which is, to say the least, very ingenious a small derived current from the supply current to energize the electromagnetic switches which, placed near the beginning of each section, switch the current into it when needed.

Fig. 1 shows a working plan of the apparatus. The car itself is supplied with two brushes at a distance apart equal to the length of a section of the working conductor, which is laid centrally between the tracks. The ends of the section are separated by insulating material and the contact length of each collector is sufficient to overlap this insulation and momentarily receive current from two adjacent sections. As a matter of fact these collectors are intended each to consist of a pair of small wheels running on the supplying rail. A glance at the diagram will show the general characteristic of the system, which differs radically from the Wheless and most similar plans in that the current which operates the switches is derived from the conductor instead of from an independent source. Closed at the start, a single one of the switches throws current into one of the sections on which the car rests, and thereafter, whether the car is moving or at rest, the operation of the parts is entirely automatic.



FIGS. 2 AND 3.—SECTIONS OF CENTRAL RAIL AND JUNCTION BOX.

Fig. 1 shows three sections of the track and three of the automatic switches. It will be seen that this switch consists of an electromagnet furnished with an armature which serves to lead the current to a projection from the working conductor. The opposite end is turned upward at right angles and forms another switch, of which the purpose will be seen later. The terminals of each magnet are connected respectively to the preceding and succeeding sections of the working conductor, to the former through the contact devices shown and directly to the latter. Suppose now the switch of the left-hand section, shown open, to be closed, and the rear collector of the car to be just leaving the section, while the forward collector is just passing from the central to the right-hand section shown. Current now passes into the first section of the working conductor, through the closed switch and also through the double contacts connected together by the rear end of the magnet armature, through the small connecting wire, to and through the magnet of the middle section, and thence to the car through the forward part of the forward brush. Thus the magnet of the central section will be energized and its armature attracted, closing the switch and letting the current pass directly from the supply conductor to the central section of the working conductor. But as soon as this switch is closed the magnet of the first section is shunted around by the low resistance and the direct connection between the supply conductor and the central section of the working conductor; hence its armature falls and, falling, breaks all connection with the first section and leaves it insulated. As the car passes on this operation is successively repeated through the following sections. The result of the arrangement then is a continuous supply to the sections immediately or nearly under the car, the remainder of the working conductor being insulated, consequently there is but little tendency to leakage, and the insulation, usually so difficult with any rail method of supply, becomes comparatively simple.

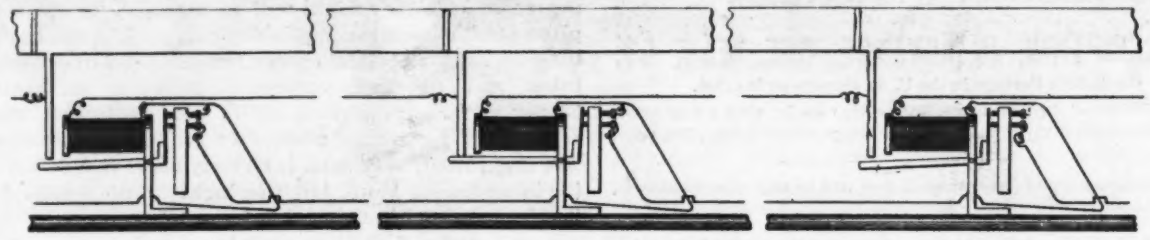


FIG. 1.—DIAGRAM OF HARDING'S CLOSED CONDUIT ELECTRIC RAILWAY.

A reasonably high potential can be used without fear of extreme leakage or of inflicting shocks from charged rails. It will, of course, be seen that this action has to be started initially by bringing one of the armatures upward into contact, thus furnishing the current necessary to operate the succeeding sections; but when this is once done it is done for the remainder of the run, or for an indefinite period, provided current is not shut off the line. A small amount of gearing is, of course, constantly wasted to operate the apparatus, being carried through the car in a special shunt. The loss, however, may be made evidently very small. A single junction box with its fittings is shown in Fig. 3, from which it will readily be seen that the apparatus may be but of small size and that the construction of the closed supply conduit is a comparatively simple matter. The junction box may be placed so close to the working conductor that the armature can, if necessary, be attracted by a permanent magnet without the necessity of opening the box for the purpose, thus allowing ready starting of the cycle of operations which has just been described. The central rail itself is intended to be fitted above a small conduit of special construction of the general form shown in Fig. 2, where the lower part of the conduit, which is a casting, contains the main supply conductor and the two small operating conductors uniting the sections all embedded in insulating material, while the upper flaring part of the conduit contains the working conductor, suitably secured and surrounded by insulating material.

It must be understood that all these electromagnetic conduit devices, in connection with the collecting devices and the resistances included in the working circuit, are in multiple arc with the motor circuit. The contact devices can be operated by the use of a very small proportion of the entire current supplied, and then the electromagnetic coils can be made of sufficiently small size to be inclosed in a conduit of moderate dimensions. One advantage of this, as of other systems of the same kind, is complete freedom from anything like inductive interference, such as is caused too frequently by overhead wires. Of course it must be understood that the earth disturbance may still exist to a certain extent, but one cause of trouble at least is removed.

The exigencies of urban electric traction have demanded some practicable method of closed conduit supply, and it certainly seems, with all the ingenuity that had been spent on the problem, that some one of the systems bearing a general resemblance to the present must finally be of considerable service. Of course, the difficulties of the multiple contacts actuated by electromagnets are considerable, and very possibly a large amount of experimentation is necessary before this complicated system of automatic switches is reduced to a thoroughly practical form; but the immense convenience of the resulting rail supply is obvious at once. There would then be no obtrusive conductors of any sort and the commercial efficiency of the system would compare favorably with the overhead arrangement. Of course, there will always be a certain amount of leakage with any conductor laid on the surface of the street, even if only a short section is charged at any one time, and there will always be a certain small waste of current in operating contact devices; but the sum of these two can be made relatively so small that there is every reason to consider the plan, on the whole, an economical one. The mechanical difficulties are the principal things to be contended with. It is much to be hoped that this or some other of the analagous plans will be put into operation on a scale sufficient to show its real virtues. A short experimental track is not enough for this purpose, for, as the number of contacts multiplies, so do the chances for disarrangement; and if a long section of track could be made to operate successfully, it is quite safe to say that the outlook for the general adoption of a practicable closed conduit system would be much improved. It is certainly a promising field for the ingenuity of the inventor and the skill of the mechanician.

Dinner of the New York Electric Club.

On Thursday evening, Oct. 2, the New York Electric Club was the scene of an unusual festivity in the shape of a particularly elegant and successful dinner, enjoyed by a strong representation of the electrical fraternity. The tables were spread in the great parlors of the club and in the adjacent dining-room, and were beautifully arranged and decorated. The parlors are especially fitted by their position and decoration to produce a more artistic effect than is at all usual at a club dinner, and the tables were decorated with a skill and grace which could hardly be surpassed.

A little before eight o'clock about 120 members of the club, and guests, sat down to what proved to be a remarkably brilliant dinner. At the head of the table sat the president of the club, Gen. O. E. Madden, and on his right and left Messrs. A. H. Patterson and G. P. Lowry. Among the decorations on the tables was a beautifully executed model of an electric car, with little incandescent lights glowing in the interior. The floral decorations, too, were especially well chosen; and the electrical character of the feast was kept up even in the molding of the ices, wherein miniature telephones and incandescent lamps attracted the guests' attention to the fact that an electrician cannot escape the evidence of his art, even when he dines.

A capital orchestra furnished selections during the dinner, to which was added a unique feature in a very successful transmission of cornet solos over loud speaking telephones. These were hidden in the great electroliers. The result was quite à la Bellamy, the middle register of the instrument being reproduced with wonderful success, although a few of the notes showed a tendency to forced over-tones that, perhaps, added to the scientific interest of the performance.

The repast was a most admirable one, and when it was finally concluded the intellectual treat of the evening began in a series of very clever after-dinner speeches, in which a number of well-known electricians and friends of electrical industry displayed their aptness at less technical pursuits. Among the speakers were: Mr. G. P. Lowry, Mr. Henry C. Davis, Mr. C. McLaren, a visitor from the great British delegation of engineers, who were then in the city, and whose remarks were specially happy and appropriate; Gen. E. S. Greeley, Capt. Zalinski, A. H. Patterson, Judge Taylor, W. D. Sargent, Mr. Charles Dutton, Mr. R. W. Raymond, and others.

Interspersed with these after-dinner exercises was music from a very excellent quartet, which added much to the pleasure of the evening.

The guests stayed well on into the small hours, and the scene was one of unalloyed jollity. It was with great regret that the assembled guests departed.

Electrical Illumination on Madison Square.

We have chosen for illustration, on the opposite page, a view of one of the public squares in this city, where the electric light has won for itself one of its most important conquests. The square, as every one knows who has visited New York City, is located at the intersection of Fifth avenue and Broadway, just above Twenty-third street, a part of the city which is not only noted for its fine business houses, but is also surrounded by a section which has been, and is yet, a favorite residence of men who have played an important part in the history of New York City's business and political enterprises.

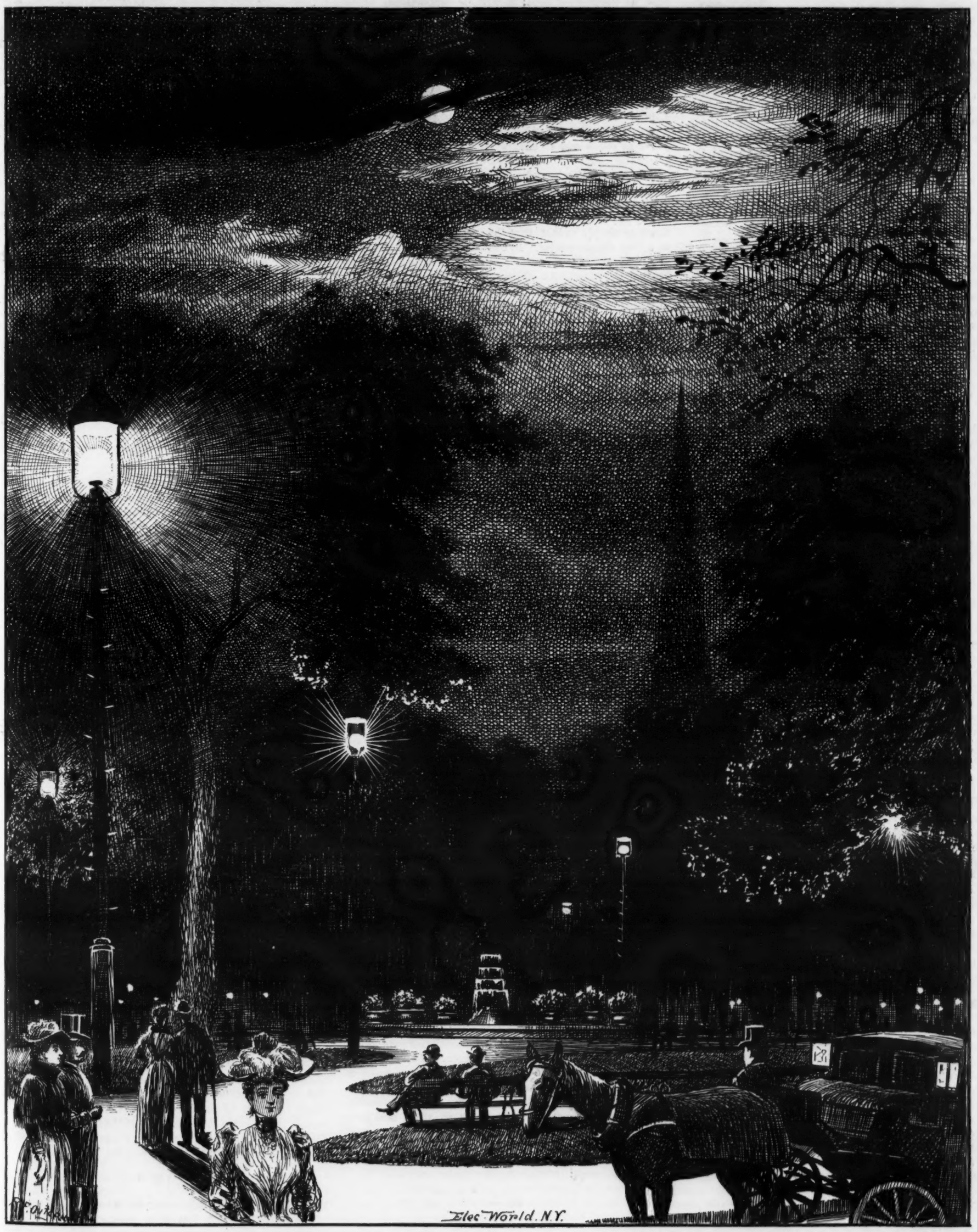
This spot is also an important one in the history of the

electric light in New York City. Upon a tall pole which stood in the centre of the square were placed arc lights, which were among the first to be used for public illumination in the city. All who were residents in the vicinity of Madison square at that time, or who visited the place for the purpose of inspecting the new method of illumination, will readily recall the striking contrast which was there exhibited between the brilliant arc lights, shining from their elevated position, and the numerous but dim and indistinct gas lights scattered about the square.

The streets leading off from Madison square are no less brilliantly illuminated than is the square itself, and visitors to the park are impressed with the beauty of the scene, as viewed from the park itself, looking down any one of the several handsome avenues which pass through it and around it. Standing upon the west side of the park, in front of the famous Fifth Avenue Hotel, one can look for miles up and down, both Fifth avenue and Broadway, and also down the splendid business thoroughfare of Twenty-third street. On the eastern side of the square is Dr. Parkhurst's Presbyterian Church. Near the centre of the park is a very fine fountain, the beauty of which, at night, is very greatly enhanced by the effect produced by the presence of the electric light, the rays of light falling through the foliage upon the spray of the fountain, making a very pretty effect.

Taken altogether, with its brilliant illumination of arc and incandescent lights along the paths of the park, through the streets surrounding it, and in the thousands of windows that look out upon it, the place probably exhibits one of the best displays of electric illumination to be found in this or any other city.

To appreciate the value of the electric light for lighting the pleasant places of the city by night, one only needs to visit a park similar in every respect except that the gas light is depended upon as the only means of illumination. Such a park is to be found in this city on Sixth avenue at the corner of Forty-second street, and, although supplied with numerous gas lights, is but dimly lighted and presents a very striking contrast to the brilliant illumination of Madison square as is well shown in our illustration on this page.



ELECTRICAL ILLUMINATION IN MADISON SQUARE, NEW YORK CITY.

The Electromagnet.*

BY PROF. SILVANUS P. THOMPSON, D. SC., B. A., M. I. E. E.

GENERAL PRINCIPLES OF DESIGN AND CONSTRUCTION—PRINCIPLE OF THE MAGNETIC CIRCUIT.

To-night we have to discuss the law of the magnetic circuit in its application to the electromagnet, and in particular to dwell upon some experimental results which have been obtained from time to time by different authorities as to the relation between the construction of the various parts of an electromagnet, and the effect of that construction on its performance. We have to deal not only with the size, section, length and material of the iron cores, and of the armatures of iron, but we have to consider also the winding of the copper coil, and its form; and we have to speak in particular about the way in which the shaping of the core and of the armature affects the performance of the electromagnet in acting on its armature, whether in contact or at a distance. But before we enter on the last more difficult part of the subject we will deal solely and exclusively with the law of force of the magnet upon its armature when the two are in contact with one another; in other words, with the law of traction.

I alluded in a historical manner in my first lecture to the principle of the magnetic circuit, telling you how the idea had gradually grown up, perforce, from a consideration of the facts. The law of the magnetic circuit was, however, first thrown into shape in 1873 by Professor Rowland, of Baltimore. He pointed out that if you consider any simple case, and find, as electricians do for the electric circuit, an expression for the magnetizing force which tends to drive the magnetism round the circuit, and divide that by the resistance to magnetization reckoned also all round the circuit, the total of those two gives you the total amount of flow or flux of magnetism. That is to say, one may calculate the quantity of magnetism that passes in that way round the magnetic circuit in exactly the same way as one calculates the strength of the electric current by the law of Ohm. Rowland, indeed, went a great deal further than this, for he applied this very calculation to the experiments made by Joule more than 30 years before, and from those experiments deduced the degree of magnetization to which Joule had driven the iron of his magnets, and by inference obtained the amount of current that he had been causing to circulate. Now this law requires to be written out in a form that can be used for future calculation. To put it in words without any symbols, we must first reckon out from the number of turns of wire in the coil, and the number of ampères of current which circulates in them, the whole *magneto-motive force*—the whole of that which tends to drive magnetism along the piece of iron—for it is, in fact, proportional to the strength of the current and the number of times it circulates. Next we must ascertain the resistance which the magnetic circuit offers to the passage of the magnetic lines. I here avowedly use Joule's own expression, which was afterward adopted by Rowland, and, for short, so as to avoid having four words, we may simply call it the *magnetic resistance*. Mr. Heaviside has suggested as an advisable alternative term magnetic *reluctance*, in order that we may not confuse the resistance to magnetism in the magnetic circuit with the resistance to the flow of current in an electric circuit. However, we need not quarrel about terms; magnetic reluctance is sufficiently expressive. Then having found these two, the quotient of them gives us a number representing—I must not call it the strength of the magnetic current—I will call it simply the quantity or number of magnetic lines which flow round the circuit; or if we could adopt a term which is used on the continent, we might call it simply *the magnetic flux*, the flux of magnetism being the analogue of the flow of electricity in the electric law. The law of the magnetic circuit may then be stated as follows:

$$\text{Magnetic flux} = \frac{\text{magneto-motive force}}{\text{reluctance.}}$$

However, it is more convenient to deal with these matters in symbols, and therefore the symbols which I use, and have long been using, ought to be explained to you. For the number of spirals in a winding I use the letter S; for the strength of current, or number of ampères, the letter i; for the length of a bar, or core, I am going to use the letter l; for the area of cross-section, the letter A; for the permeability of iron which we discussed in the last lecture, the Greek symbol μ; and for the total magnetic flux, the number of magnetic lines, I use the letter $\mathbf{N}$. Then our law becomes as follows:

$$\text{Magneto-motive force } \frac{4\pi \cdot Si}{10};$$

$$\text{Magnetic reluctance } \Sigma \frac{l}{A\mu};$$

$$\text{Magnetic flux..... } \mathbf{N} = \frac{\frac{4\pi \cdot Si}{10}}{\Sigma \frac{l}{A\mu}}.$$

If we take the number of spirals and multiply by the number of ampères of current, so as to get the whole amount of circulation of electric current expressed in so many ampère turns, and multiply by 4π, and divide by 10, in order to get the proper unit (that is to say, multiply it by 1.2566); that gives us the magneto-motive force. For magnetic reluctance, calculate out the reluctance exactly as you would the resistance of an electric conductor to the flow of electricity, or the resistance of a conductor of heat to the flow of heat; it will be proportional to the length, inversely proportional to the cross-section, and inversely proportional to the conductivity, or, in the present case, to the magnetic permeability. Now if the circuit is a simple one, we may simply write down here the length, and divide it by the area of the cross-section and the permeability, and so find the value of the reluctance. But if the circuit be not a simple one, if you have not a simple ring of iron of equal section all round, it is necessary to consider the circuit in pieces as you would an electric circuit, ascertaining separately the reluctance of the separate parts, and adding all together. As there may be a number of such terms to be added together, I have prefixed the expression for the magnetic reluctance by the sign Σ of summation. But it does not by any means follow, because we can write a thing down as simply as that, that the calculation out of it will be a very simple matter. In the case of magnetic lines we are quite unable to do as one does with electric currents to insulate the flow. An electric current can be confined (provided we do not put it in at 10,000 volts pressure, or anything much bigger than that) to a copper conductor by an adequate layer of adequately strong—and I use the word "strong" both in a mechanical and electrical sense—of adequately strong insulating material. There are materials whose conductivity for electricity as compared with copper may be regarded perhaps as millions of millions of millions of times less; that is to say, they are practically perfect insulators. There are no such things for magnetism. The most highly insulating substance we know of for magnetism is certainly not 10,000 times less permeable to magnetism than the most highly magnetizable substance we know of, namely, iron in its best condition; and when one deals with electromagnets where curved portions of iron are surrounded with copper, or with air, or other insulating material, one is dealing with substances whose permeability, instead of being infinitely small compared with the iron, is quite considerable. We have to deal mainly with iron when it has been well magnetized. Its permeability compared with air is from 1,000 to 100 roughly; that is to say, the permeability of air compared with the iron is not less than from $\frac{1}{100}$th to $\frac{1}{1000}$th part. That means that it is quite possible to have a very considerable leakage of magnetic lines from iron into air occurring to complicate one's calculations and prevent an accurate estimate being made of the true magnetic reluctance of any part of the circuit. Suppose, however, that we have got over all these difficulties and made our calculations of the magnetic reluctance; then dividing the magnetomotive force by the reluctance gives us the whole number of magnetic lines.

There, then, is in its elementary form the law of the magnetic circuit stated exactly as Ohm's law is stated for electric circuits. But, as a general rule, one requires this magnetic law for certain applications, in which the problem is not to calculate from those two quantities what the total of magnetic lines will be. In most of the cases a rule is wanted for the purpose of calculating back. You want to know how to build a magnet so as to give you the requisite number of magnetic lines. You start by assuming that you need to have so many magnetic lines, and you require to know what magnetic reluctance there will be, and how much magnetomotive force will be needed. Well, that is a matter precisely analogous to those which every electrician comes across. He does not always want to use Ohm's law in the way in which it is commonly stated, to calculate the current from the electromotive force and resistance; he often wants to calculate what is the electromotive force which will send a given current through a known resistance. And so do we. Our main consideration to-night will be devoted to the question how many ampère turns of copper wire winding must be provided in order to drive the required quantity of magnetism through any given magnetic reluctance. Therefore, we will state our law a little differently. What we want to calculate out is the number of ampère turns required. When once we have got that, it is easy to say what the copper wire must consist of, what sort of wire, and how much of it. Turning then to our algebraic rule, we must transform it, so as to get all the other things besides the ampère turns to the other side of the equation. So we write the formula:

$$Si = \frac{\mathbf{N} \cdot \Sigma \frac{l}{A\mu}}{1.257}$$

We shall have then the ampère turns equal to the number of magnetic lines we are going to force round the circuit multiplied by the sum of the magnetic reluctances divided by 1.257. Now this number, 1,257, is the constant that comes in when the length l is expressed in centimetres, the area in square centimetres, and the permeability in the usual numbers. Many persons unfortunately—I say so advisedly because of the waste of brain labor that they have been compelled to go through—prefer to work in inches and pounds and feet. They have, in fact, had to learn tables instead of acquiring them naturally without any learning. If the lengths be specified in inches and areas in square inches, then the constant is a little different. The constant in that case, for inches and square inch measures, is 0.3133, so that the formula becomes:

$$Si = \mathbf{N} \times \Sigma \frac{l''}{A''\mu} \times 0.3132.$$

Here it is convenient to leave the law of the magnetic circuit, and come back to it from time to time as we require. What I want to point out before I go to any of the applications is, that with the guidance provided by this law, one after another the various points that come under review can be arranged and explained, and that there does not now remain—if one applies this law with judgment—a simple fact about electromagnets which is either anomalous or paradoxical. Paradoxical some things may seem in form, but they all reduce to what is perfectly rational when one has a guiding principle of this kind to tell you how much magnetization you will get under given circumstances, or to tell you how much magnetizing power you require in order to get a given quantity of magnetization. I am using the word "magnetization" there in the popular sense, not in the narrow mathematical sense in which it has sometimes been used (*i. e.*, for the magnetic moment per unit cube of the material). I am using it simply to express the fact that the iron or air, or whatever it may be, has been subjected to the process which results in there being magnetic lines of force induced through it.

Now let us apply this law of magnetic circuit in the first place to the traction, that is to say, the lifting power of electromagnets. The law of traction I assumed in my last lecture, for I made it the basis of a method of measuring the amount of permeability. The law of magnetic traction was stated once for all by Maxwell, in his great treatise, and it is as follows:

$$P\,(\text{dynes}) = \frac{\mathbf{B}^2 A}{8\pi}$$

where A is the area in square centimetres. This becomes

$$P\,(\text{grammes}) = \frac{\mathbf{B}^2 A}{8\pi \times 981}$$

That is, the pull in grammes per square centimetre is equal to the square of the magnetic induction, $\mathbf{B}$ (being the number of magnetic lines to the square centimetre), divided by 8π, and divided also by 981. To bring grammes into pounds you divide by 453.6, so that the formula then becomes:

$$P\,(\text{lbs.}) = \frac{\mathbf{B}^2 A}{11{,}183{,}000};$$

or if square inch measures are used:

$$P\,(\text{lbs.}) = \frac{\mathbf{B}^2 A''}{72{,}134{,}000}.$$

To save future trouble we will now calculate out from the law of traction the following table; in which the traction in grammes per square centimetre or in pounds per square inch is set down opposite the corresponding value of $\mathbf{B}$.

TABLE VI.—MAGNETIZATION AND MAGNETIC TRACTION.

$\mathbf{B}$ lines per sq. cm.	$\mathbf{B}_{''}$ lines per sq. in.	Dynes per sq. centim.	Grammes per sq. centim.	Kilogrs. per sq. centim.	Pounds per sq. inch.
1,000	6,450	39,790	40.56	.0456	.577
2,000	12,900	159.200	162.3	.1623	2.308
3,000	19,350	358,100	365.1	.3651	5.190
4,000	25,800	636,600	648.9	.64:9	9.228
5,000	82,250	994,700	1,014	1.014	14.39
6,000	38,700	1,432,000	1,460	1.460	20 75
7,000	45,150	1,950,000	1,987	1.987	28.26
8,000	51,600	2,547,000	2,596	2.596	36.95
9,000	58,050	3,223,000	3,286	3.286	46.72
10,000	64,500	3,979,000	4,056	4.056	57.68
11,000	70,950	4,815,000	4,907	4.907	69.77
12.000	77,400	5,730,000	5,841	5 841	83.07
13,000	83,850	6,725,000	6,855	6.855	97.47
14,000	90,300	7,800,000	7,550	7.550	113.1
15,000	96,750	8,953,000	9,124	9.124	129.7
16,000	103,200	10,170,000	10,390	10.39	147.7
17,000	109,650	11.500,000	11.720	11 72	166.6
18,000	116,100	12,890.000	13,140	13 14	186.8
19,000	122,550	14,360,000	14,630	14 63	208.1
20,000	129,000	15,920,000	16,230	16.23	230.8

This simple statement of the law of traction assumes that the distribution of the magnetic lines is uniform all over the area we are considering; and that unfortunately is not always the case. When the distribution is not uniform then the mean value of the squares becomes greater than the square of the mean value, and consequently the pull of the magnet at its end face may, under certain circumstances, become greater than the calculation would lead you to expect—greater than the average of $\mathbf{B}$ would lead you to suppose. If the distribution is not uniform over the area of contact then the accurate expression for the tractive force (in dynes) will be

$$P = \frac{1}{8\pi}\int \mathbf{B}^2\, dA,$$

the integration being taken over the whole area of contact.

The law of traction has been verified by experiment. The most conclusive investigations were made about 1886 by Mr. R. H. M. Bosanquet, of Oxford, whose apparatus is depicted in Fig. 22. He took two cores of iron, well faced, and surrounded them both by magnetizing coils, fastened the upper one rigidly, and suspended the other one on a lever with a counterpoise weight. To the lower end of this core he hung a scale-pan, and measured the traction of one upon the other when a known current was circulating a known number of times round the coil. At the same time he placed an exploring coil round the joint, that exploring coil being connected, in the

* Cantor Lectures, No. 2.

manner with which we were experimenting last week, with a ballistic galvanometer, so that at the moment when the two surfaces parted company, or at the moment when the magnetization was released by stopping the magnetizing current, the galvanometer indication enabled you to say exactly how many magnetic lines went through that exploring coil. So that, knowing the area, you could calculate the number per square centimetre, and you could therefore compare B^2 with the pull per square centimetre obtained directly on the scale-pan. Bosanquet found that even when the surfaces were not absolutely perfectly faced the correspondence was very close indeed, not varying by more than one or two per cent. except with small magnetizing forces. such as with forces than five C. G. S. units. When one knows how irregular the behavior of iron is in weak magnetic fields forces are so small as this, one is not astonished to find a lack of proportionality. The correspondence was, however, sufficiently exact to say that the experiments verified the law of traction, and the pull is proportional to the square of the magnetic induction through the area integrated over that area.

Now the law of traction being in that way established, one at once begins to get some light upon the subject of the design of electromagnets. Indeed, without going into any mathematics, Joule had foreseen this when he in some instinctive sort of way seemed to consider that the proper way to regard an electromagnet for the purpose of traction was to think how many square inches of contact surface it had. He found that he could magnetize iron up until it pulled with a force of 175 pounds to the square inch, and he doubted whether a traction as great as 200 pounds per square inch could be obtained.

In the following table Joule's results (see Table I., p. 240) are recalculated, and the values of **B** deduced:

TABLE VII.—JOULE'S RESULTS RE-CALCULATED.

Description of Electromagnet.		Section.		Load.		Lbs. per sq. in.	Kilos. per sq. cm.	B	Ratio of load to weight.
		sq.in.	sq. cen	lbs.	kilos.				
Joule's own electromagnet...	No. 1	10	64.5	209.0	947	104.5	7.35	13,600	139
	No. 2	0.196	1.26	49	22	125	8 75	14,700	324
	No. 3	0.0436	6.28	12	5.4	137.5	9.75	15,410	1,286
	No. 4	0.0012	0.0077	0.202	0.09	81	5.7	11,830	2 384
Nesbit's		4.5	29.1	142.8	647	158.5	11.2	16,550	28
Henry's		3.94	25 3	750	346	95	6.7	12,820	36
Sturgeon's		0 196	1.26	53	22.6	127.5	8.95	14,850	114

I will now return to the data on Table VI., and will ask you to compare the last column with the first. Here are various values of **B**, that is to say, the amounts of magnetization you get into the iron. You cannot conveniently crowd more than 20,000 magnetic lines to the square centimetre of the best iron, and, as a reference to the curves of magnetization shows, it is not expedient in the practical design of electromagnets to attempt, except in extraordinary cases, to crowd more than 16,000 magnetic lines into the square centimetre. The simple reason is this: that if you are working up the magnetic force, say from 0 up to 50, a magnetizing force of 50 applied to good wrought iron will give you only 16,000 lines to the square centimetre, and the permeability by that time has fallen to about 320. If you try to force the magnetization any further, you find that you have to pay for it so greatly. If you want to force another 1,000 lines through the square centimetre, to go from 16,000 to 17,000, you have to add on an enormous magnetizing force; you have to double the whole force from that point to get another 1,000 lines added. Obviously it would be much better to take a larger piece of iron and not to magnetize it too highly—to take a piece a quarter as large again, and to magnetize that less forcibly. It does not therefore pay to go much above 16,000 lines to a square centimetre—that is to say, expressing it in terms of the law of traction, and the pounds per square inch, it does not pay to design your electromagnet so that it shall have to carry more than about 150 pounds to the square inch. This shall be our practical rule: let us at once take an example. If you want to design an electromagnet to carry a load of one ton, divide the ton, of 2,240 lbs., by 150, and that gives the requisite number of square inches of wrought iron, namely, 14.92, or say 15. Of course one would work with a horse-shoe shaped magnet, or something equivalent—something with a return circuit—and calculate out the requisite cross-section, so that the total area exposed might be sufficient to carry the given load at 150 lbs. to the square inch. And, as a horseshoe magnet has two poles, the cross-section of the bar of which it is made must be $8\frac{1}{2}$ square inches. If of round iron, it must be about $3\frac{1}{4}$ inches in diameter; if of square iron, it must be $2\frac{3}{4}$ inches each way.

That settles the size of the iron, but not the length. Now, the length of the iron, if one only considers the law of the magnetic circuit, ought to be as short as it can possibly be made. Reflect for what purpose we are designing. The design of an electromagnet is to be considered, as every design ought to be, with a view to the ultimate purpose to be served by that which you are designing. The present purpose is the actual sticking on of the magnet to a heavy weight, not acting on another magnet at a distance, not pulling at an armature separated from it by a thick layer of air; we are dealing with traction in contact. The question is, How long a piece of iron shall we need to bend over? The answer is: Take length enough, and no more than enough, to permit of room for winding on the necessary quantity of wire to carry the current which will give the requisite magnetizing power. But this latter we do not yet know; it has to be calculated out by the law of the magnetic circuit. That is to say, we must calculate the magnetic flux, and the magnetic reluctance as best we can; then from these calculate the ampère turns of current; and from this calculate the needful quantity of copper wire, so arriving finally at the proper length of the iron core. It is obvious the cross-section being given and the value of **B** being prescribed, that settles the whole number of magnetic lines, **N**, that will go through the section. It is self-evident that length adds to the magnetic resistance, and, therefore, the longer the length is, the greater have to be the number of ampère turns of circulation of the current; while the less the length, the smaller need be the number of ampère turns of circulation. Therefore you should design the

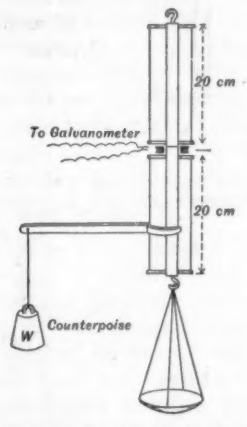


FIG. 22.—BOSANQUET'S VERIFICATION OF THE LAW OF TRACTION.

electromagnet as stumpy as possible, that is to say make it a stumpy arch, even as Joule did when he came across the same problem, and arrived, by a sort of scientific instinct, at the right solution. You should have no greater length of iron than is necessary in order to get the windings on. Then you see we cannot absolutely calculate the length of the iron until we have an idea about the winding, and we must settle, therefore, provisionally, about the windings. Take a simple ideal case. Suppose we had an indefinitely long, straight iron rod, and we wound that from end to end with a magnetizing coil. How thick a coil, how many ampère turns of circulation per inch length will you require in order to magnetize up to any particular degree? It is a matter of very simple calculation. You can calculate exactly what the magnetic reluctance of an inch length of the core will be. For example, if you are going to magnetize up to 16,000 lines per square centimetre, the permeability will be 320. You can take the area anything you like, and consider the length of one inch; you can therefore calculate the magnetic reluctance per inch of conductor, and then you can at once say how many ampère turns per inch would be necessary in order to give the desired indication of 16,000 magnetic lines to the square centimetre. And knowing the properties of copper wire, and how it heats up when there is a current; and knowing also how much heat you can get rid of per square inch of surface, it is a very simple matter to calculate what minimum thickness of copper the fire insurance companies would allow you to use. They would not allow you to have too thin a copper wire, because if you provide

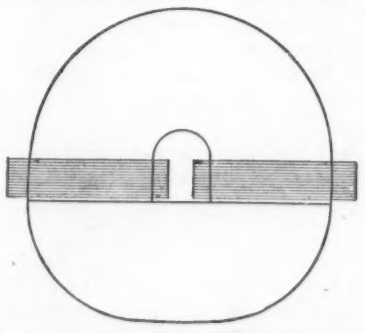


FIG. 23.—STUMPY ELECTROMAGNET.

an insufficient thickness of copper you still must drive your ampères through it to get a sufficient number of ampère turns per inch of length; and if you drive those ampères through copper winding of an insufficient thickness the copper wire will overheat and your insurance policy will be revoked. You therefore are compelled, by the practical consideration of not overheating, to provide a certain thickness of copper wire winding. I have made a rough calculation for certain cases, and I find that for such electromagnets as one may ordinarily deal with, it is not necessary in any case of practical work to use a copper wire winding, the total thickness of which is greater than about half an inch; and, as a matter of fact, if you use as much as half an inch, you need not then wind the coil all along, for if you will use copper wire winding, no matter what the size, whether thin or thick, so that the total thickness of copper outside the iron is half an inch, you can without overheating, using good wrought iron, make one inch of winding do for 20 inches length of iron. That is to say, you do not really want more than $\frac{1}{10}$th of an inch of thickness of copper outside the iron to magnetize up to the prescribed degree of saturation that indefinitely long piece of which we are thinking, without overheating the outside surface in such a way as to violate the insurance rules. Take it roughly, if you wind to a thickness of half an inch the inch length of copper will magnetize 20 inches length of iron up to the point where **B** equals 16,000. If then we have a bar bent into a sort of horseshoe in order to make it stick on to a perfectly-fitting armature also of equal section and quality, we really do not want more than one inch along the inner curve for every 20 inches of iron. An extremely stumpy magnet, such as I have sketched in Fig. 23, will therefore do, if one can only get the iron sufficiently homogeneous throughout. If, instead of crowding the wire near the polar parts, we could wind entirely all round the curved part, though the layer of copper winding would be half an inch thick inside the arch, it would be much less outside. Such a magnet, provided the armature fitted with perfect accuracy to the polar surfaces, and provided a battery were arranged to send the requisite number of ampères of current through the coils, would pull with a force of one ton, the iron being but $3\frac{1}{4}$ inches in diameter. For my own part, in this case I should prefer not to use round iron, one of square or rectangular section being more convenient; but the round iron would take less copper in winding, as each turn would be of minimum length if the section were circular.

Now, this sort of calculation requires to be greatly modified directly one begins to deal with any other case. A stumpy short magnetic circuit with great cross-section is clearly the right thing for the greatest traction. You will get the given magnetization and traction with the least amount of magnetizing force when you have the area as great as possible, and the length as small as possible. You will kindly note that I have given you as yet no proofs for the practical rules that I have been using; they must come later. Also I have said nothing about the size of the wire, whether thick or thin. That does not in the least matter, for the ampère turns of magnetizing power can be made up in any desired way. Suppose we want on any magnet 100 ampère turns of magnetizing power, and we choose to employ a thin wire that will only carry half an ampère, then we must wind 200 turns of that thin wire. Or, suppose we choose to wind it with a thick wire that will carry 10 ampères, then we shall want only 10 turns of that wire. The same weight of copper, heated up by the corresponding current to an equal degree of temperature, will have equal magnetizing power when wound on the same core. But the rules about winding the copper will be considered later.

Now if you look in the text-books that have been written on magnetism for information about the so-called lifting power or portative force of magnets—in other words, the traction—you will find that from the time of Bernoulli downwards, the law of portative force has claimed the attention of experimenters, who, one after another, have tried to give the law of portative force in terms of the weight of the magnets; usually dealing with permanent magnets, not electromagnets. Bernoulli gave * a rule something of the following kind, which is commonly known as Häcker's rule:

$$P = a\sqrt[\frac{3}{2}]{W};$$

where W is the weight of the magnet, P the greatest load it will sustain, and a a constant depending on the units of weight chosen, on the quality of the steel and on its goodness of magnetization. If the weights are in pounds, then a is found for the best steels to vary from 18 to 24 in magnets of horseshoe shape. This expression is equivalent to saying that the power which a magnet can exert—he was dealing with steel magnets; there were no electromagnets in Bernoulli's time—is equal to some constant multiplied by the three-halfth root of the weight of the magnet itself. The rule is accurate only if you are dealing with a number of magnets all of the same geometrical form, all horseshoes, let us say, of the same general shape, made from the same sort of steel, similarly magnetized. In former years I pondered much on Häcker's rule, wondering how on earth the three-halfth root of the weight could have anything to do with the magnetic pull; and, having cudgeled my brains for a considerable time, I saw that there was really a very simple meaning in it. What I arrived at† was this: If you are dealing with a given material, say hard steel, the weight is proportional to the volume, and the cube root of the volume is something proportional to the length, and the square of the cube root forms something proportional to the square of the length, that is to say, to something of the nature of a surface. What surface? Of course the polar surface. This complex rule when thus analyzed turns out to be merely a mathematician's expression of the fact that the pull for a given material magnetized in a given way is proportional to the area of the polar surface; a law which in its simple form Joule seems to have arrived at naturally, and which in this extraordinarily academic form was arrived at by comparing the weights of magnets with the weight which they would lift. You will find it stated in many books that a good magnet will lift 20 times its own weight. There never was a more fallacious rule written It is perfectly true that a good steel horseshoe

*_Acta Helvetica_, III., p. 233, 1758.

†_Philosophical Magazine_, July, 1888.

magnet weighing one pound ought to be able to pull with a pull of 20 pounds on a properly-shaped armature. But it does not follow that a magnet which weighs 2 pounds will be able to pull with a force of 40 pounds. It ought not to, because a magnet that weighs 2 pounds has not poles twice as big if it is the same shape. In order to have poles twice as big you must remember that three-halfth root coming in. If you take a magnet that weighs eight times as much, it will have twice the linear dimensions and four times the surface; and with four times the surface in a magnet of the same form, similarly magnetized, you will have four times the pull. With a magnet eight times as big you will have only four times the pull. The pull, when other things are equal, goes by surface and not by weight, and therefore it is ridiculous to give a rule saying how many times its own weight a magnet will pull. It is also narrated as a very extraordinary thing that Sir Isaac Newton had a magnet, a loadstone, which he wore in a signet ring, which would lift 234 times its own weight. I have had an electromagnet which would lift 2,500 times its own weight, but then it was a very small one, and did not weigh more than a grain and a half. When you come to small things, of course the surface is large proportionally to the weight; the smaller you go, the larger becomes that disproportion. This all shows that the old law of traction in that form was practically valueless, and did not guide you to anything at all, whereas the law of traction as stated by Maxwell, and explained further by the law of the magnetic circuit, proves a most useful rule.

From this digression let us return to the law of the magnetic circuit. I gave you in my first lecture, when speaking of permeability, the following rule for calculating the magnetic induction **B**: Take the pull in pounds, and the area of cross-section in square inches; divide one by the other, and take the square root of the quotient; then multiplying by 1,317 gives **B**; or multiplied by 8,494 gives $\mathbf{B}_{,,}$. We have therefore a means of stepping from the pull per square inch to $\mathbf{B}_{,,,}$ or from $\mathbf{B}_{,,}$ to the pull per square inch. Now the other rule of the magnetic circuit also enables us to get from the ampère turns down to $\mathbf{B}_{,,,}$ for on page 258, we have the following expression for the ampere turns:

$$Si = \mathbf{N} \times \Sigma \frac{l''}{A'' \mu} \times 0.3132,$$

and **N**, the whole number of magnetic lines in the magnetic circuit, is equal to $\mathbf{B}_{,,}$ multiplied by A'', or

$$\mathbf{N} = \mathbf{B}_{,,} A''.$$

From these we can deduce a simple direct expression, provided we assume the quality of iron as before, and also assume that there is no magnetic leakage, and that the area of cross-section is the same all round the circuit, in the armature as well as in the magnet core. In that case l'' is simply the total length of the mean path of the magnetic lines all round the closed magnetic circuit. We may then write:

$$Si = \frac{\mathbf{B}_{,,} l''}{\mu} \times 0.3132;$$

whence

$$\mathbf{B}_{,,} = \frac{\mu \times Si}{l'' \times 0.3132}.$$

But by the law of traction, as stated above,

$$\mathbf{B}_{,,} = 8{,}494 \sqrt{\frac{P \text{ (lbs.)}}{A \text{ (sq. in.)}}}$$

Equating together these two values of $\mathbf{B}_{,,}$, and solving, we get for the requisite number of ampère turns of circulation of exciting currents:

$$Si = 2.661 \times \frac{l''}{\mu} \times \sqrt{\frac{P \text{ (lbs.)}}{A \text{ (sq. in.)}}}$$

This, put into words, amounts to the following rule for calculating the amount of exciting power that is required for an electromagnet pulling at its armature, in the case where there is a closed magnetic circuit with no leakage or magnetic lines. Take the square root of the pounds per square inch; multiply this by the mean total length (in inches) all round the iron circuit; divide by the permeability (which must be calculated from the pounds per square inch by help of Table VI. and Table II.), and finally multiply by 2,661; the number so obtained will be the number of ampère turns. One goes then at once from the pull per square inch to the number of ampère turns required to produce that pull in a magnet of given length and of the prescribed quality. In the case where the pull is specified in kilogrammes, the area of section in square centimetres, and the length in centimetres, the formula becomes

$$Si = 3{,}951 \cdot \frac{l}{\mu} \sqrt{\frac{P}{A}}.$$

As an example, take a magnet core of round annealed wrought iron, half an inch in diameter, eight inches long, bent to horseshoe shape. As an armature, another piece, four inches long, bent to meet the former. Let us agree to magnetize the iron up to the pitch of pulling with 112 pounds to the square inch. Reference to Table VI. shows that $\mathbf{B}_{,,}$ will be about 90,000, and Table II. shows that in that case μ will be about 907. From these data calculate what load the magnet will carry, and how many ampère turns of circulation of current will be needed.

Ans.—Load (on two poles) = 43.97 lbs.

Ampere turns needed = 372.5

N. B.—In this calculation it is assumed that the contact surface between armature and magnet is perfect. It never is; the joint offers additional reluctance to the magnetic lines, and there will be some leakage. It will be shown later how to estimate these effects, and to allow for them in the calculations.

Here let me go to a matter which has been one of the paradoxes of the past. In spite of Joule, and of the laws of traction, showing that the pull is proportional to the area, you have this anomaly—that if you take a bar magnet having flat ended poles, and measure the pull which its pole can exert on a perfectly flat armature, and then deliberately spoil the truth of the contact surface, rounding it off, so making the surface gently convex, the convex

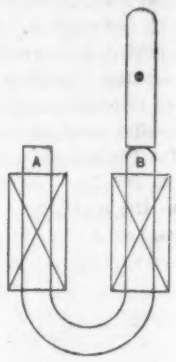


Fig. 24.—Experiment on Rounding Ends.

pole, which only touches at a portion of its area instead of over the whole, will be found to exert a bigger pull than the perfectly flat one. It has been shown by various experimenters, particularly by Nicklès, that if you want to increase the pull of a magnet with armatures you may reduce the polar surface. Old steel magnets were frequently purposely made with a rounded contact surface. There are plenty of examples. Suppose you take a straight round core, or use one leg of a horseshoe, which will answer the purpose equally well, and take a flat-ended rod of iron of the same diameter as an armature; stick it on endwise, and measure the pull when a given amount of ampère turns of current

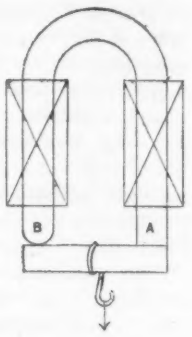


Fig. 24a.—Experiment of Detaching Armature.

is circulating round. Then, having measured the pull, remove it and file it a little, so as to reduce it at the edges, or take a slightly narrower piece of iron, so that it will actually be exerting its power over a smaller area, you will get a greater pull. What is the explanation of this extraordinary fact? A fact it is, and I will show it to you. Here, Fig. 24, is a small electromagnet which we can place with its poles upward. This was very carefully made, the iron poles very nicely faced, and on coming to try them it was found they were nearly equal, but one pole, *A*, was a little stronger than the other. We have, therefore, rounded the other pole, *B*, a little, and here I will take a piece of iron, *C*, which has itself been slightly

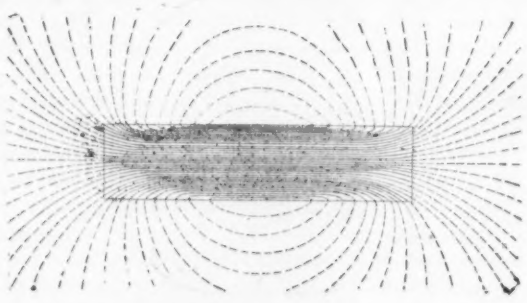


Fig. 25.—Lines of Force Running through Bar Magnet.

rounded at one end, though it is flat at the other. I now turn on the current to the electromagnet, and I take a spring balance so that we can measure the pull at either of the two poles. When I put the flat end of *C* to the flat pole *A* so that there is an excellent contact, I find the pull about 2¼ pounds. Now try the round end of *C* on the flat pole *A;* the pull is about three pounds. The flat end of *C* on the round pole *B* is also about three pounds. But if now I put together two surfaces that are both rounded I get almost exactly the same pull as at first with the two flat surfaces. I have made many experiments on this, and so have others. Take the following case: There is hung up a horseshoe magnet (Fig. 24a), one pole being slightly convex and the other absolutely flattened, and there is put at the bottom, a square bar armature, over which is slipped a hook to which weights can be hung. Which end of the armature do you think will be detached first?

If you were going simply by the square inches, you would say this square end will stick on tighter; it has more gripping surface. But, as a matter of fact, the other sticks tighter. Why? We are dealing here with a magnetic circuit. There is a certain total magnetic reluctance all round it, and the whole number of magnetic lines generated in the circuit depends on two things—on the magnetizing force, and on the reluctance all round; and, saving a little leakage, it is the same number of magnetic lines which come through at *B* as go through that at *A*. But here, owing to the fact there is at *B* a better contact at the middle than at the edges of the pole, the lines are crowded into a smaller space, and therefore at that particular place $\mathbf{B}_{,,}$ the number of lines per square inch runs up higher, and when you square the larger number, its square becomes still larger in proportion. In comparing the square of smaller $\mathbf{B}_{,,}$ with the square of greater $\mathbf{B}_{,,}$, the square of the smaller $\mathbf{B}_{,,}$ over the larger area turns out to be less than the square of the larger $\mathbf{B}_{,,}$ integrated over the smaller area. It is the law of the square coming in.

As an example, take the case of a magnet pole formed on the end of a piece of round iron 1.15 square inches in diameter. The flat pole will have 1.05 inches area. Suppose the magnetizing forces are such as to make $\mathbf{B}_{,,} = 90{,}300$, then by Table VI. the whole pull will be 118.75 pounds, and the actual number of lines through the contact surface will be $\mathbf{N} = 948{,}150$. Now suppose the pole be reduced by rounding off the edge till the effective contact area is reduced to 0.9 square inch. If all these lines were crowded through that area, that would give a rate of 105,630 per square inch. Suppose, however, that the additional reluctance and the leakage reduced the number by two per cent., there would still be 103,500 per square inch. Reference to Table VI. shows that this gives a pull of 147.7 pounds per square inch, which, multiplied by the reduced area 0.9, gives a total pull of 132.9 pounds, which is larger than the original pull.

It must not be supposed because rounding one pole makes a larger traction that therefore rounding both poles of the horseshoe is desirable. Reducing the contact area of one pole, though it may strengthen the pull on that pole, *diminishes* the pull on the *other* pole, for it strangles the magnetic circuit.

Let me show you yet another experiment. This is the same electromagnet which has one flat pole and one rounded pole. Here is an armature, also bent, having one flat and one rounded pole. If I put flat to flat and round to round, and pull at the middle, the flat to flat detaches first; but if we take round to flat and flat to round, we shall probably find they are about equally good—it is hard to say which holds the more strongly.

The law of traction can again be applied to test the so-called distribution of free magnetism on the surface. This is a subject on which I shall have to say a good deal. We must therefore carefully consider what is meant by the phrase. Let Fig. 25 be a rough drawing of an ordinary bar magnet. Every one knows that if we dip such a magnet into iron filings the small bits of iron stick on more especially at the ends, but not exclusively, and if you hold it under a piece of paper or cardboard, and sprinkle iron filings on the paper, you obtain curves like those shown on the diagram. They attest the distribution of the magnetic forces in the external space. The magnetism running internally through the body of the iron begins to leak out sideways, and, finally, all the rest leaks out in a great tuft at the end. These magnetic lines pass round to the other end and there go in again, and the place where the steel is internally most highly magnetized is this place across the middle, where externally no iron filings at all stick to it. Now, we have to think of magnetism from the inside and not the outside. This magnetism extends in lines, coming up to the surface somewhere near the ends of the bar, and the filings stick on wherever the magnetism comes up to the surface. They do not stick on at the middle part of the bar, where the metal is really most completely permeated through and through by the magnetism; there are a larger number of lines per square centimetre of cross-section in the middle region where none come up to the surface, and no filings stick on. Now, we may explore the leakage of magnetic lines at various points of the surface of the magnet by the method of traction. We can thereby arrive at a kind of measure of the amount of magnetism that is leaking, or, if you like to call it so, of the intensity of the "free magnetism" at the surface. I do not like to have to use these ancient terms, because they suggest the ancient notion that magnetism was a fluid or, rather, two fluids, one of which was plastered on at one end of the magnet, and the other at the other, just as you might put red paint or blue paint over the ends. I only use that term because it is already more or less familiar. Here is one of the ways of experimentally exploring the so-called distribution of free magnetism. The method was, I believe, originally due to Plücker; at any rate, it was much used by him. This little piece of apparatus was arranged by my friend and predecessor, Prof. Ayrton, for the purpose of teaching his students at the Finsbury College. Here is a bar magnet of steel, marked in centimetres from end to end; over the top of it there is a little steel-yard, consisting of a weight sliding along an arm. At the end of that steel-yard there is suspended a small bullet of iron. If we bring that bullet into contact with the bar magnet anywhere near the end, and equilibrate the pull by sliding the counterpoise along the steel-yard arm, we shall obtain the definite pull required to detach that piece of iron. The pull will be proportional, by Maxwell's rule, to the square of the number of magnetic

lines coming up from the bar into it. Shift the magnet on a whole centimetre, and attach the bullet a little further on; now equilibrate it, and we shall find it will require a rather smaller force to detach it. Try it again, at points along from the end to the middle. The greatest force required to detach it will be found at the extreme corner, and a little less a little way on, and so on until we find at the middle the bullet does not stick on at all, simply because there are here no magnetic lines leaking. The method is not perfect, because it obviously depends on the magnetic properties of the little bullet, and whether much or little saturated with magnetism. Moreover, the presence of the bullet perturbs the very thing that is to be measured. Leakage into air is one thing; leakage into air perturbed by the presence of the little bullet of iron, which invites leakage into itself, is another thing. It is an imperfect experiment at the best, but a very instructive one. This method has been used again and again in various cases for exploring the apparent magnetism on the surface. I shall use it hereafter, reserving the right to interpret the result by the light of the law of traction.

(To be Continued.)

Recent Determinations of the Absolute Resistance of Mercury.*

BY R. T. GLAZEBROOK, F. R. S.

We are here to-day to discuss some of the determinations of the value of the ohm when expressed as the resistance of a column of mercury, with a view to seeing if any action is practicable by which the standards in general use may be brought nearer to their theoretical value than they are at present. The time is opportune, for we have the advantage of having in Leeds Professor Mascart, of Paris, and Professor Rowland, of Baltimore, under whose directions some of the most important of the investigations we are to consider to-day have been made, and Professor Barker, one of the American representatives at the Paris Congress. Moreover, it seems probable that a congress will again meet shortly to consider this question, and a preliminary discussion here may be of value in clearing the ground.

The question at issue is whether the results of experiment are sufficiently in accord with each other to render it probable that any number adopted by us would be generally accepted, and, if so, to determine what that number is.

VALUE OF OHM EXPRESSED AS THE RESISTANCE OF A COLUMN OF MERCURY.

	Observer.	Date.	Method.	Value of B. A. U. in ohms.	Value of 100 centimetres of mercury in B. A. U.	Value of ohm in centimetres of mercury.
1	Lord Rayleigh	1882	Rotating coil	.98651	.95412	106.24
2	Lord Rayleigh	1883	Lorenz method	.98677	.....	106.21
3	G. Wiedemann	1884	Rotation through 180 deg	.....	.....	106.19
4	Mascart	1884	Induced current	.98611	.95374	106.33
5	Rowland	1887	Mean of several methods	.98644	.95349	106.32
6	Kohlrausch	1887	Damping of magnets	.98660	.95338	106.32
7	Glazebrook	1882 and '88	Induced currents	.98665	.95352	106.29
8	Wuilleumeier	1890	.....	.98686	.95355	106.27
		Mean	.....	.98656		
9	Strecker	1885	An absolute determination of resistance was not made. The value .98656 has been used	.....	.95334	106.32
10	Hutchinson	1888			.95352	106.30
11	Salvioni	1890			.95332 or .95404	106.33
12	..					
	Mean without 12				.95355	106.28

	Observer.	Date.	Method.	Value of B. A. U. in ohms.	Value of 100 centimetres of mercury in B. A. U.	Value of ohm in centimetres of mercury.
13	H. F. Weber	1884	Induced current	Absolute measurements compared with German silver wire coils issued by Siemens or Strecker.		105.37
14	H. F. Weber	....	Rotating coil			106.16
15	Roiti	1884	Mean effect of induced current			105.89
16	Himstedt	1885	.....			105.98
17	Dorn	1889	Damping of a magnet			106.24
18	Wild	1883	" "			106.03
19	Lorenz	1885	Lorenz method			105.93

The problem has two sides. The resistance of a wire is expressed by means of one series of experiments in terms of a length and a time, while by another series of experiments it is expressed in terms of the resistance of mercury, and thus the resistance of mercury is found absolutely. Frequently, however, there is an intermediate step; the resistance of the wire is expressed in terms of some standard resistance, and this standard is expressed in terms of mercury.

The methods employed to compare a standard resistance with that of mercury are all very similar in their nature, and the experiment is not one of very great difficulty. Accordingly we find that the results of the experiments are fairly concordant.

In Table I., column 5 gives the values found in B. A. units for the resistance of a column of mercury 1 metre long, 1 square millimetre in section at 0° C.—a Siemens unit as it is called. The values found by Lord Rayleigh and M. Mascart are higher than later ones. A comparison of the values found for the B. A. U. in ohms and for the Siemens unit in B. A. U. by M. Mascart, leads to the conclusion that possibly his B. A. U. had changed a little between the time at which it was compared with the standards at Cambridge and the time at which it was used. As to Lord Rayleigh's value, the fact that the coil F was his principal standard, and that coil F has certainly changed relatively to the other coils in the last two years, may help to explain the difficulty, but it must be remembered that F had the same value relatively to the others in 1888 as it had in 1881, when examined by Dr. Fleming, and some other cause for the difference must be sought. The other numbers are in close accord, except one result of Salvioni's, which must, I think, be capable of a simple explanation. Strecker, Kohlrausch and Salvioni differ somewhat from Wilkes and myself, in consequence, I believe, of the fact that they worked at the temperature of the room, while Wilkes and I worked at the temperature of melting ice. A small change in the temperature coefficient used by them would easily account for the difference. Wuilleumeier's mercury tubes were the same as those employed by Mascart, Benoit and de Nerville. We may thus take .5953 B.A.U. as being very accurately the resistance of a column of mercury 100 centimetres long, 1 square millimetre in section.

But when we inquire what are the results which have been obtained for the value in ohms of the B. A. U., or of the mercury unit, the discrepancies are considerable.

Let us consider the methods. An admirable summary of these will be found in Wiedemann's *Electricitat*, Vol. IV., p. 910, or in Mascart and Joubert's *Leçons sur l'Electricité*, Vol. II., pp. 581, *et seq.* They have also been critically discussed by Wiedemann and by Lord Rayleigh in the *Phil. Mag.*, Vol. XVI., 1882. We will take them in order.

I. Kirchhoff's Method.

This has been used by H. F. Weber, Rowland, Mascart and Glazebrook. The formula may be written

$$R = \frac{4\pi M}{T} \cdot h \cdot \frac{a}{\beta},$$

Where M is the coefficient of induction between the coils, T the time of swing of the galvanometer needle, a the deflection due to the primary current, β the throw due to the induced current, and h a ratio either of two galvanometer constants, or of two resistances; all small corrections are omitted.

The main difficulty is in calculating the value of M, which depends approximately on a^2/b, if a is radius of either coil and b the distance between the coils.

In the coils used by myself the value of a was about 26 centimetres; that of b varied from 12 to 24 centimetres. An error of .1 millimetre in b produces an error in the result between 1 in 1,500 and 1 in 2,000. In one position of the coils the correction arising from the fact that the cross-section of the channel was of finite area was less than 1 in 1,000. There should, it seems to me, be no difficulty in finding M to one or two in 10,000. The coils used by Rowland and Weber in their earlier experiments, and by Mascart, were smaller. In his last experiment in 1883 Weber used coils of 32 centimetres radius. In their later experiments Rowland and Kimball had large coils, about 50 centimetres in radius.

The various results are:

H. F. Weber	105.37
Rowland	106.29
Mascart	106 33
Glazebrook	106.29

It will be noticed that all H. F. Weber's results are very low. He used as his standard wire a 10 Siemens unit taken from a resistance-box, not a coil which had been compared directly with mercury, and it seems possible that a common error in this affects all his results; he also used large magnets. The other values are in fair agreement, though we may probably agree with Lord Rayleigh in thinking that the limit of accuracy of the method has not been reached.

II.—Weber's Method.

The approximate formula again is

$$R = \frac{2\pi Gg}{T\beta} = \frac{4\pi^2 NN'}{T\beta}\frac{a^2}{A},$$

where G is the constant of the galvanometer, g the area of the earth inductor, and in the second expression a is the radius of the inductor, A of the galvanometer, N and N' the number of turns on either.

This method was followed by Mascart, who used with a coil of 15 centimetres diameter and a galvanometer the constant for which was compared with one of known constant, viz., the inductor. The time taken to turn the inductor was one-fifth of the time of vibration of the galvanometer needle. There is the difficulty of making the axis vertical and the effect of the time of duration of the current on the throw of the galvanometer needle to consider. My experiments show that if the effect of the induction current be prolonged for a period of one second the time of swing being 23 seconds, then the deflections are reduced by .1 per cent. With the circuit open for two seconds effects are marked.

The same method has been used by G. Wiedemann, who is inclined to think it the best; he employed coils of W. Weber and Zollner, one metre in diameter, which were wound and measured twice. He calculated G, using as galvanometer coil a counterpart of the inductor; the effect of the current was determined by measuring the effects of a series of impulses at proper moments. The time of turning the inductor was two seconds, while the period of the needle was one minute. This would tend to reduce β, this to increase R, and hence to decrease the length of the column, which was found by comparison with a Siemens unit; the same unit was compared with mercury.

Mascart thinks difficulties inspire with doubt the results thus obtained. Experiments near the magnetic equator would, Lord Rayleigh points out, decrease the effect of level error. Wiedemann considers this method is to be recommended for final determinations. Rowland criticises the method.

The results obtained are :

Mascart	106.37
Wiedemann	106.19

III.—Method of British Association Committee.

$$R = \pi^2 N^2 a \Omega \cot. \varphi$$

The only measurement, apart from corrections, is that of mean radius. The corrections, however, are important, for the self-induction of the rotating coil requires to be known; while the magnetic field in which the coil is moving is modified by the presence of the magnet at its centre, so that the magnetic moment of this magnet has to be determined. In order to reduce the amount of this correction, this magnetic moment is made small, and this again leads to difficulties.

The following difficulties are urged by Wiedemann:

(1) Correction due to self-induction. (2) Difficulty of leveling. (3) Want of steadiness from draughts, etc. (4) Small magnetic moment.

In reply we may say

(1) Can be corrected for.

(2) Level error common to several methods. (See II. above.)

(3) Effect can be eliminated by experiments with open circuit.

(4) Theory of the correction is very simple; a knowledge of M/H only is required.

The method was used by Lord Rayleigh, leading to the result, 106.24. It was also employed by H. F. Weber, who used rotation about a horizontal diameter in the magnetic meridian to avoid the correction depending on M/H.

IV.—Foster and Lippmann.

$$R = 2\ \pi^2 \Omega \frac{a^2}{A} \cot \varphi\ NN'.$$

A rotating coil is used, but contact is made only at the moment when the E. M. F. is a maximum, and E. M. F. is balanced by that due to an external current through a known resistance. Observations have been recently carried out by Wuilleumeier by this method with modifications. He used the induction from a long spiral $M\,N$ (see figure), 2 metres long, 30 centimetres diameter, placed east and west, wound with one layer of wire 2 millimetres in diameter. A coil, C, wound on a disc of hard wood 20 centimetres in diameter, rotates in this, and the circuit is closed when the E. M. F. in C is a maximum; the E. M. F. thus produced is balanced against that produced by the current in the spiral when flowing through a resistance, R, the action of the earth's magnetism being compensated. One point, A, of R is in connection with the coil through E; the other end is straight, and a movable contact is established at A_1, A_2, etc. Corrections for its ends are obtained by shifting the spiral coil. The resistance of R was about .3 ohm, made from a strip of German silver of rectangular section 34.72 metres long, 1 centimetre broad, .3 centimetre thick, immersed in naphtha. The primary current was 12 ampères. A Lippmann electrometer was used. The E. M. F. was nearly four volts. The diameter of the rotating bobbin was 20 centimetres. Hence, error of 1 millimetre in mean radius makes error of one in 1,000. The formula assumes spiral to be uniformly wound. Result is 106.267.

V.—Method of Damping.

Set a magnet in a coil. The motion of the magnet sets up currents which react on the magnet and damp it. A relation can be found between these currents and the rate of damping. To a first approximation, λ λ_0 being logarithmic decrements, is

$$R = \frac{\pi}{2}\ \frac{1}{T}\ G^2\ \frac{M}{H}\ \frac{(\pi^2 + \lambda^2)}{\lambda - \lambda_0}$$

G has to be compared with the constant of another coil because of the size of the coil. Let h be the ratio—

$$R = \frac{2\pi^2}{T}\ \frac{N^2 h^2}{A^2}\ \frac{\pi^2 + \lambda^2}{\lambda - \lambda_0}\ r^3 \tan a$$

Where A is the radius of the standard coil, N the number of its turns, a the deflection which the magnet produces in Gauss' first position when at a distance, r.

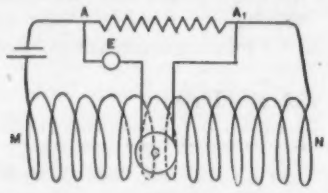
*Printed from notes used for the discussion on Electrical Units in Section A of the British Association, Leeds, 1890.

Further corrections are required for length of magnet, and for the uncertainty as to the distribution of its magnetism and for self-induction. In the opinion of Lord Rayleigh and Rowland, the final formula is enough to show that it cannot compete with the others. Other difficulties are that the calculation assumes the arc of oscillation is small, G is not independent of the displacement. Currents are set up in the magnet, which affect its motion. A correction is required for temporary induced magnetization due to action of current; this may be appreciable. In general there are difficulties in applying the theory.

The method was used by H. F. Weber. His magnet was 8 centimetres long, his coil 16 centimetres in radius, and G was calculated, a uniform distribution of magnetism being assumed.

Dorn introduced corrections to the theory; he found G by comparison with a large coil, compared result with a Siemens unit, verified by Strecker; his magnet was 17 centimetres long, closely surrounded by the coil. Wild suspended the magnet bifilarly; it was 29 centimetres long, and the coil closely surrounded it; a resistance box used.

Kohlrausch's magnet was 20 centimetres long, with brass



Foster and Lippmann's Method of Determining the Resistance of Mercury.

ends. The coil was close to it; G was compared with a large galvanometer. Resistance compared directly with a tube calibrated by Strecker.

The results are:

H. F. Weber	104.77
Dorn	106.24
Wild	106.03
Kohlrausch	106.32

VI.—Lorenz Method.

$$R = n\,M.$$

The main difficulty lies in the calculation of M; this is more easy than in I, for the disc can readily be measured.

In Lord Rayleigh's apparatus an error in the radius of the coil does not greatly affect the result. Further increase of size possible and desirable. The smallness of the effect, and therefore of R, is not fatal. See Lord Rayleigh's observations.

Thermo-electric effects can be compensated for.

Results:

Rayleigh	106.24
Rowland	106.29
Lorenz	106.19

Lorenz value is too low, because of the size of the mercury tubes used by him.

VII.—Roiti and Himstedt.

$$R = n\,M\,\frac{a}{\beta} = n\,4\,\pi^2\,a^2\,\frac{N\,N}{1}\,\frac{a}{\beta}$$

There is a difficulty in having many contacts, for if the contact does not last all the time supposed, β would be too small, R too large, and the length of the column too short. There is also an important correction for the ends, and the assumption is made that the coils are uniformly wound. Another difficulty is the theory of the galvanometer under such discharges.

The resistances were compared with a Siemens unit, and in the case of Roiti with one of Strecker's coils.

The results are:

Roiti	105.89
Himstedt	105.98

VIII.—Calorimetric Methods.

The results by these methods cannot claim any great accuracy.

Having thus completed the review of the methods, we must look at the results; and after what I have said we may, I think, reject all work previous to 1882.

RESULT OF OBSERVATIONS ON THE VALUE OF THE OHM.

Induction Effect—Kirchhoff's Method.

1878.	Rowland	106.16
1882.	Glazebrook	106.29
1883.	Kimball	106.25
1884.	Mascart	106.30
1884.	H. F. Weber	105.37
1884.	Rowland	106.31
	Mean	106.26

Method of B. A. Committee.

1865.	B. A. Committee	104.83
1881.	Lord Rayleigh	105.95
1882.	Lord Rayleigh	106.25
1882.	H. F. Weber	106.16
	Mean	106.20

Lorenz Method.

1873.	Lorenz	107.10
1883.	Lord Rayleigh	106.22
1884.	Lorenz	106.19
1884.	Lenz	106.13
1884.	Rowland	106.29
1885.	Lorenz	105 93
	Mean	106.15

The results of H. F. Weber are manifestly too low, while serious doubts attach to the methods of Roiti and Himstedt. For Weber's first method, the early results of W. Weber and Zollner may be omitted compared with those of G. Wiedemann, while the results given by the method of damping will be sufficiently represented by the work of F. Kohlrausch, who alone of those who used this method compared his results with the resistance of mercury directly. The experiments of Lorenz will not, I think, stand rigid criticism, while, unless I am much mistaken, Lenz, who also used Lorenz's method, has only published results and not details.

We are thus left with the following list, including the results only of those who have made both the mercury and absolute determinations:

Lord Rayleigh	106.23
Mascart	106.33
G. Wiedemann	106.19
Rowland	106 32
Kohlrausch	106.32
Glazebrook	106.29
Wullleumeier	106.27
Mean	106.28

If we take in Lord Rayleigh's results for the value of the B. A. U. in ohms, for 100 centimetres of mercury in B. A. U. the value .9535 instead of .9541, as given by his own experiments, we get, instead of the values 106.21 and 106.24, the values 106.27 and 106.30. The mean, then, of the whole would be 106.29. If we include the three numbers (9, 10, 11) of the table we get the value 106.30.

It seems then, to me, that the number 106.30 certainly expresses the true value within one or two in 10.000, and that the time has come for carrying the conclusions of the Paris Congress one place further. The establishment of the new standardizing laboratory calls for some authoritative expression of opinion here in England. Are we prepared to express our opinion?

In 1886, the Standards Committee agreed, on the motion of Sir W. Thomson, (1) to recommend for adoption for a term of 10 years the legal ohm of the Paris Congress as a legalized standard sufficiently near to the absolute ohm for commercial purposes, and (2) that at the end of 10 years the legal ohm should be defined to a closer approximation to the absolute ohm. The government took no action on this matter, and the opportunity is afforded us of revising, not in ten years, but in four, our provisional suggestion. Shall we replace the 106 centimetres by 106.30 centimetres? For my part I should be guided greatly by the amount of acceptance that such a decision would meet with. If Prof. Roland and Prof. Barker, who were with us in 1886, can tell us that they would agree in recommending the government of the United States to adopt the same view, and if Prof. Mascart thinks that such a course would meet with the approval of himself and his distinguished colleagues in France, I should be heartily glad of it. If, on the other hand, they press for further time in order that experiments of a higher degree of accuracy—which can no doubt be attained, though probably at great cost—may be carried out, I should deprecate the committee coming to any conclusion which might pledge them to a number which does not meet with general acceptance.

Contributions to the Molecular Theory of Induced Magnetism.*

BY J. A. EWING, F. R. S.

The chief facts of permeability and retentiveness, and hysteresis generally, are therefore at once explicable by supposing that Weber's molecular magnets are constrained by no other forces than those due to their own mutual magnetic attractions and repulsions. No arbitrary constraining forces are required. In the model the centres of rotation are fixed; in regard to the actual solid we may

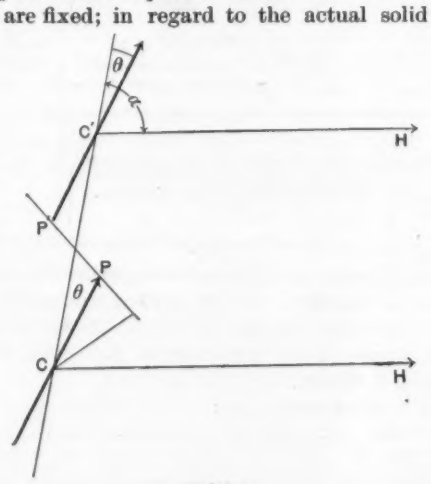


Fig. 7.

make an equivalent supposition, namely, that the distances between the molecular centres do not change (except in so far as they may be changed by strain).

Hysteresis, then, is not the result of any quasi-frictional resistance to molecular rotations; it occurs whenever a molecule turns from one stable position of rest to another through unstable condition. When it is forced to return, it again passes through a condition of instability. This process, considered mechanically, is not reversible; the forces are different for the same displacement, going and coming, and there is dissipation of energy. In the model the energy thus expended sets the little bars swinging, and heir swings take some time to subside. In the actual solid the energy which the molecular magnet loses as it swings through unstable positions generates eddy currents in surrounding matter. Let the magnets of the model be furnished with air-vanes to damp their swings, and the correspondence is complete.

A regular group of elementary magnets, especially when furnished with air-vanes, gives a good illustration of what has been called magnetic viscosity. When the imposed force H reaches a critical value one of the outer members of the group becomes unstable, and swings slowly round; its next neighbors, finding their stability weakened, follow suit, and the disturbance spreads through the group in a way eminently suggestive of those phenomena of time-lag in magnetization which I have described in a former paper.*

The model shows equally well other magnetic phenomena which presumably depend on the inertia of the molecules, such as the fact that a given force causes more magnetic induction when suddenly applied than when gradually applied, and leaves less residual magnetism when suddenly removed than when gradually removed.

The well-known effects of mechanical vibration in augmenting magnetic susceptibility and reducing retentiveness are readily explicable when we consider that vibration will cause periodic changes in the distances between molecular centres. This has not only a direct influence in

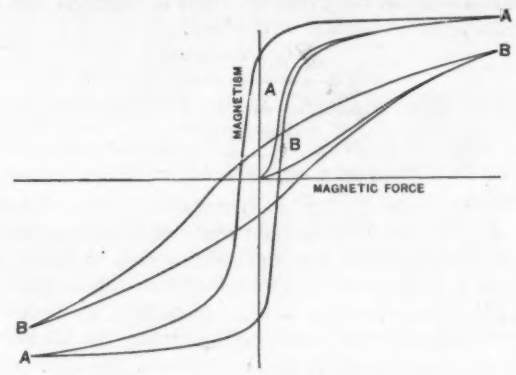


Fig. 8.

making the molecular magnets respond more easily to changes of magnetic force by reducing their stability during the intervals when they recede from each other, but tends indirectly toward the same result by setting them swinging.

The effects of temperature which are common to the three magnetic metals may be stated thus: Let any moderate magnetizing force be applied, not strong enough to produce anything like an approach to magnetic saturation, and let the temperature be raised. Then the permeability *increases* until the temperature reaches a certain (high) critical value, at which, almost suddenly, there is an almost complete disappearance of magnetic equality. As regards the first effect, it is clear that an increase of permeability is to be expected from the theory; expansion with rise of temperature involves a separation of the molecule centres, and therefore a reduction of stability. As regards the almost sudden loss of susceptibility which occurs at a high temperature, it may do no harm to hazard a rather wild conjecture. We may suppose the molecular magnets to be swinging more or less, the violence of the swings increasing as the temperature rises, until finally it develops into *rotation*. Should this happen all trace of polarity would of course disappear. The conjecture that the molecular magnets oscillate more and more as the temperature rises is at least supported by the fact (carefully investigated by Hopkinson† in iron and nickel; data for cobalt also have lately been supplied by Du Bois‡) that under *strong* magnetic forces rise of temperature reduces magnetism; for with strong forces the molecular magnets are already ranged so that their mean direction is nearly parallel to H; hence the earlier effect of heat (to diminish stability and facilitate alignment) does not tell, and the increased swinging simply results in reducing the mean value for each molecule of its moment resolved parallel to the magnetizing force.

Before referring to effects of stress we may consider shortly the stability of a pair or line of magnets, treating each as a pair of poles subject to the law of inverse squares. Take first a single pair of equal magnets with centres at C and C' (Fig. 7). The poles PP' would lie in the line CC', but for the imposed force H, which produces a deflection $CC'P$ or $C'CP = \theta$.

Let a be the angle which H makes with the line of centres, m the pole strength, and r the half length of the magnetic axis of each magnet. The deflecting moment is

$$2\,\mathsf{H}\,mr\sin(a-\theta),$$

and the restoring moment is

$$\frac{m^2\overline{CN}}{\overline{PP'}^2},$$

CN being drawn normal to PP'. The restoring moment at first increases with θ, but passes a maximum at a value of θ which depends on the relation of r to the distance between the centres. The condition of equilibrium is

$$2\,\mathsf{H}\,mr\sin(a-\theta) = \frac{m^2\overline{CN}}{\overline{PP'}^2};$$

and as H and θ are increased the equilibrium becomes neutral, that is to say, the condition of instability is reached, when

$$\frac{d}{d\theta}\left\{2\,\mathsf{H}\,mr\sin(a-\theta\right\} = \frac{d}{d\theta}\,\frac{m^2\overline{CN}}{\overline{PP'}^2}$$

These two equations serve to determine the value of H and of θ at which instability occurs. If we have to deal

*Paper read before the Royal Society, June 19, 1890. Continued from The Electrical World, Oct. 4, 1890.

*Proc. Roy. Soc., June, 1889.
†*Phil. Trans.*, 1889, A, p. 443; *Proc.* Roy. Soc., June, 1888.
‡*Phil. Mag.*, April, 1890.

with a long line of magnets instead of a single pair, we have to write $2m^2$ instead of m^2 in the restoring moment.

A considerable amount of stable deflection is possible when the distance between the poles is not small compared with r. When the direction of H is not much inclined to CC' (that is, when a has a value approaching 0) there is no instability. In rows with various inclinations to H, the first to become unstable as H is increased will be that for which $a - \theta$ is equal to $\frac{1}{2}\pi$.

If a, the half distance between the poles in the undeflected position, be small compared with r, there is but little deflection before instability occurs, and in that case, provided a be not small, nor nearly equal to π, the occurrence of instability is defined by the condition

$$\frac{d}{d\theta}\frac{\overline{CN}}{\overline{PP'}^2} = 0,$$

which is satisfied when $\tan\varphi = \frac{1}{\sqrt{2}}$; φ being the inclination of PP' to the line of centres. Hence, with the same proviso (a not nearly equal to 0 or to π, and a small compared with r), the value of H which causes the instability is

$$\mathsf{H} = \frac{m}{12\sqrt{3}\cdot a^2 \sin a}$$

for a single pair of magnets, and twice this quantity for the middle members of a long row. This is, of course, least for magnets which lie normal to H.

In the special case when $a = \pi$, instability occurs when

$$\mathsf{H} = \frac{m}{8a^2}$$

with the single pair, or $m/4a^2$ with the row.

Applied to the case of a group of rows, uniform in distance between the centres, but various as regards their direction with respect to H, these considerations show that after H has reached a value sufficient to make the most susceptible members unstable no very great increase is required to bring about instability in by far the greater number of the other rows. One general effect of increasing the distance between all the centres is to reduce the range of variation of H within which most of the different rows become unstable as the force is progressively increased.

In annealed metal, where we may expect considerable general homogeneity, as regards distance between the centres of the molecular magnets, we find that practically the whole of the abrupt stage in the process of magnetization is included within narrow limits of magnetizing force. We accordingly obtain curves like AA (Fig. 8). When the metal is strained sufficiently to receive permanent set the curves take more rounded outlines (such as BB), showing less susceptibility throughout, less residual magnetism, and more coercive force. The most natural explanation of this, on the basis of the molecular theory, appears to be that set produces on the whole a shortening of the distances between molecular centres, hence greater stability and more coercive force; but this is associated with heterogeneity, that is variety in the distances, hence the rounded outlines of the curves. We know that set tends to develop, or at least to emphasize, heterogeneity; for instance, a bar of iron or steel pulled in the testing machine stretches irregularly after the elastic limit is passed.

The effects of stress and consequent elastic strain on magnetic quality are so complex and so various in iron, nickel and cobalt that it would be premature to attempt any full discussion of them from the point of view of the theory now sketched. Only a few general features need be referred to at present. Some of these can be traced experimentally in the model by setting the supports of the magnets upon a sheet of thin india rubber, which may be stretched or distorted to imitate the conditions of longitudinal or torsional strain.

When pulling stress is applied those rows of molecular magnets which lie more or less along the direction of the stress have their stability reduced by the lengthening of the lines of centres; similarly, rows which lie more or less normal to the stress have their stability increased. The resulting effect on the general susceptibility of the material will depend on which of these conflicting influences preponderates. Let pull be applied before magnetization begins, while the metal is still in a neutral state. The stretching of longitudinal lines and the contraction of transverse lines will not only alter the stability of those molecules which continue to lie in their original rows, but will tend to make the members of those rows which are much lengthened swing round and form transverse lines, in which they will be more stable than before. We may, therefore, reasonably expect that the permeability with regard to strong fields will be reduced by pull, as it actually is, both in iron and in nickel, though with regard to weak fields the permeability may be increased, as it is in iron.

Again, the theory explains well why the effects of stress are by no means the same, (1) when the stress is applied first and the magnetic force after, and (2) when the magnetic force is applied first and the stress after. Let a moderate magnetizing force be applied, and then begin to apply stress. The first effects are in general large, for the strain precipitates into instability those molecular magnets which were already on the verge of instability. This is beautifully apparent in iron (see *Phil. Trans.*, 1885, Part II., plates 63 and 64); and the theory shows why the first effects are not reversible, why they do not disappear when the stress is removed, and why it is only in subsequent applications and removals of the stress that the magnetic changes become cyclic. The same remark evidently applies to the first effects of stress on residual magnetism; also to the first effects of temperature change either on induced or residual magnetism. Again, the theory shows that when a cyclic change of stress is repeated, there will be hysteresis in the corresponding changes of magnetism, whether induced or residual, unless either the cyclic range is very small or the magnetism approaches saturation. During each application of the stress some molecular magnets will swing through unstable positions; during the removal of stress they will swing back, but not at the same values of stress. And it will be characteristic of this hysteresis that the variation in magnetism will begin slowly when the change from applying to removing stress, or from removing to applying stress, begins. All this agrees with the facts.

Moreover, the theory shows that even in the absence of any resultant magnetization a cycle of stress makes the molecular configuration pass through a series of changes which will at first not be cyclic, but will become cyclic when the stress-cycle is repeated, and in which any intermediate value of the stress will be associated with different configurations during the going and coming parts of the process. In other words, we see that there will be hysteresis in the relation of molecular configuration to stress when a cycle of stress is repeated. Hence certain rather obscure effects which have been observed in magnetic experiments; for instance, where an iron wire is loaded and partially unloaded down to a given load before being magnetized, its permeability is not the same as when the wire is completely unloaded and reloaded up to the same load. Experimental results of this kind led me in 1884 to write: "If we apply and remove stress in a wire whose magnetic state is entirely neutral, *we cause some kind of molecular displacement in the relation of which to the applied stress there is hysteresis.*"* The theory now offered shows how this happens. Hence also the remarkable hysteresis which the thermo-electric quality of iron exhibits with regard to cyclic changes of stress, discovered by Cohn, and more fully described in *Phil. Trans.*, 1886, p. 361. The hysteresis of molecular configuration with respect to stress has been proved to be removable or reducible by vibration.

From this theoretical explanation of hysteresis in the effects of stress, it at once follows that a cyclic change of stress (provided it be not very small) involves some dissipation of energy in a magnetic metal, whether the piece be magnetized or not. We may expect this dissipation to be most considerable under conditions which make the magnetic hysteresis large. But it will occur even when there is no external trace of magnetism. This, of course, implies that, in a cyclic process of loading and unloading, work must be spent. There is no perfect elasticity in a magnetic metal, however slowly the process of straining be performed. Under any load there is less strain during application than during removal. This is borne out by experiments on the extension of iron wires (Brit. Assoc. Report, 1889, p. 502). The same action occurs to a marked degree in torsional strains. In a twisted specimen there will be a tendency on the part of the molecular magnets to range themselves along lines agreeing more or less with the direction of maximum contraction. Alternate twisting to opposite sides should therefore cause much molecular swinging through unstable positions, with consequent dissipation of energy, even in a piece which is not magnetized. Without going at present into details, it may be added that the phenomena of molecular "accommodation" studied by Wiedemann and by H. Tomlinson accord with the theory, and that it seems to lend itself well to explain the very remarkable results which have been obtained by Nagaoka† in experiments with nickel wire under twist or under a combination of pull and twist. It also agrees with what little is known as to the influence that previous magnetization in one direction has upon subsequent magnetization in another direction.

To sum up, I have endeavored to show:

(1) That in considering the magnetization of iron and other magnetic metals to be caused by the turning of permanent molecular magnets, we may look simply to the magnetic forces which the molecular magnets exert on one another as the cause of their directional stability. There is no need to suppose the existence of any quasi-elastic directing force or of any quasi-frictional resistance to rotation.

(2) That the intermolecular magnetic forces are sufficient to account for all the general characteristics of the process of magnetization, including the variations of susceptibility which occur as the magnetizing force is increased.

(3) That the intermolecular magnetic forces are equally competent to account for the known facts of retentiveness and coercive force and the characteristics of cyclic magnetic processes.

(4) That magnetic hysteresis and the dissipation of energy which hysteresis involves are due to molecular instability resulting from intermolecular magnetic actions, and are not due to anything in the nature of frictional resistance to the rotation of the molecular magnets.

(5) That this theory is wide enough to admit explanation of the differences in magnetic quality which are shown by different substances or by the same substance in different states.

(6) That it accounts in a general way for the known effects of vibration, of temperature, and of stress upon magnetic quality.

(7) That in particular it accounts for the known fact that there is hysteresis in the relation of magnetism to stress.

(8) That it further explains why there is, in magnetic metals, hysteresis in physical quality generally with respect to stress, apart from the existence of magnetization.

(9) That, in consequence, any (not very small) cycle of stress occurring in a magnetic metal involves dissipation of energy.

* *Phil. Trans*, 1885, Part II., p. 614.

† *Journal* of the College of Science of the University of Tokio, Vol. II., 1888.

Ore Dressing by Electricity at the Tilly Foster Mine.*

BY F. H. M'DOWELL.

The electromagnetic separator of G. Conkling, Glens Falls, N. Y., described by Mr. Birkinbine† in a paper at the New York meeting of the institute in February, 1889, has been in successful operation at the Tilly Foster mine for a considerable period, under the disadvantages which seem to be the inevitable attendants of pioneer enterprises in new technical fields. The results of a run of several months, which the superintendent, S. P. Tompkins, has taken pains to collate, are here presented.

The process includes crushing the ore by a Blake rock breaker on the dump; removing it in train loads to the bins in the mill; passing it under two Ball stamps, provided with screens of 5-16 inch mesh; elevating it to the Conkling electrical separating belts; and delivering the concentrates to the cars and the tailings to the settling reservoirs. The mill has been kept running almost continuously ten hours out of the twenty-four, and this has contributed not a little to the success of the undertaking.

During the six months ending July 31, 1890 (the work of January being omitted from the calculation), there were treated 18,058 tons of lean ore, an average of 3,009 tons per month. The concentrates produced amounted to 6,236 tons, an average of 1,039 tons per month. There were required, therefore, 2 89 tons of crude ore to produce one ton of concentrates. The average cost of treatment, including preparing the ore and getting it to mill, and disposing of the tailings (which items make up one-half of the charge for labor), was $2.25 per ton of concentrates. The actual expenses in the mill have averaged $1.63 per ton of concentrates. These figures will be materially reduced when the supply of waste ore from the dump has been exhausted, and a higher grade of lean ore is sent directly from the mine to the mill.

The figures of August show 1,391 tons concentrates from 3,508 tons of crude ore, or 1:2.52. The cost per ton of concentrates was $1.89, as compared with $2.39 in July. The reduction of cost is due to the increased output of the mill in concentrates, a larger amount of crude ore having been treated, and also a larger yield obtained per ton of crude ore.

The following practical conclusions are suggested by these results:

1. Unless the location and other conditions are exceptionally favorable, it will not pay to erect works to treat the material of waste dumps carrying less than 25 per cent. of iron.

2. Where the lean ore is mined in connection with shipping ore, there must be a corresponding increase in the percentage of iron to offset the mining and royalty charges.

3. Where no shipping ore is produced, there must be a still further increase in the percentage of iron, to warrant the erection of hoisting, pumping and dressing works.

* Abstract of a paper read at the New York meeting of the American Institute of Mining Engineers, Sept. 29, 1890.

† See Transactions of the Am. Inst. of Min. Eng., XVII., 739.

The Magnetization of Iron Ore.‡

BY CLEMENS JONES.

On rapidly drying a small sample of limonite over a powerful Bunsen flame on one occasion, I observed that the smaller particles were magnetized. Could the ore be magnetized? A trial on a more practical scale convinced me that such was the case. I then experimented with several different ores, and found that all the ore particles were so strongly affected as to permit their complete separation by means of a magnet.

Naturally, a series of experiments followed, in every instance giving the same results. My attention was then directed toward finding out the conditions as well as the cause of the phenomenon. This led me to the conclusion that the agency of heat in the presence of carbon or carbon dioxide magnetizes the hydrous oxides of iron.

The surprisingly small amount of ferrous oxide in the magnetized ore leaves the question whether magnetization is wholly due to its presence very uncertain. In some cases the raw ore contains nearly 3.07 per cent. of ferrous oxide. If the reduction caused by roasting were the sole cause, it would be reasonable to expect the exterior of the particle to be the magnetized portion. But lumps of the roasted ore having been broken, small pieces, carefully selected from the inside of the lumps, showed in some cases even more strongly marked magnetic properties.

A number of trials with the anhydrous oxide, both red and specular hematites, conducted in precisely the same

‡ Abstract of a paper read at the New York meeting of the American Institute of Mining Engineers, Sept. 29, 1890.

manner. gave no evidence whatever of resulting magnetization. Crystallized specimens remained likewise unaffected. While the porous character of the brown hematite would permit permeation by reducing gases, it is difficult to understand how such minute deoxidation could magnetize it so strongly. Moreover, the magnetization appears to be permanent. Samples which I have kept for over a year in contact with air have preserved the quality unimpaired. Cooling the red-hot oxide in water affects it somewhat, but it is still capable of responding through that medium to the attraction of a magnetic field.

The phenomenon seems to be connected with the expulsion of the combined water, and I think is largely dependent on its physical separation from the ore. During the process some of the oxides glow quite strongly. The raw oxide, when heated to redness in a closed gas tube, gives off a small amount of carbonic acid with its water, but is only feebly magnetic. There is no apparent evidence that ferrous oxide is produced by decomposition of the water. The only statement now possible is that the hydrated oxides of iron become magnetized at a red heat in contact with carbon or carbon dioxide.

It may be worth noting that the idea of employing a magnetic separator in a process for "manufacturing cast steel and malleable iron of a superior and uniform quality directly from ores" was announced some years ago in a United States patent by E. L. Seymour, 1867. The curious supposition on which it was based was that when "impure ores" are brought to a white heat in a furnace (thereby producing metallic sponge) they can be separated from "pure ores" by the "simple mechanism of revolving magnets." Some of the "noxious elements" thus to be eliminated were "titanic acid, vanadic acid, chromic acid, sulphuric acid, sulphur, phosphorus, phosphoric acid, silicic acid, silicates." The resulting product was to be simply melted.

It is of course a logical deduction that all hydrous ores of iron become magnetic in the blast furnace, and that at the proper zone even anhydrous hematite does so. Ore concentrated as above described is peculiarly adapted to use in the blast furnace. Before the ore particles reach a red heat in the process of roasting, violent decrepitation takes place, thus breaking or splitting up into small fragments all the lumps of ore. This state is most desirable for rapid reduction in the blast furnace, and, aided by the easy fusibility of the ore, offers the most favorable conditions for "driving" and regularity of work.

Electric Power Transmission in Coal Mines.*

BY H. C. SPAULDING.

Basing our judgment on the world's advance in scientific developments during the last century, we may reasonably conclude that in no other country would the pioneers of electrical invention, whose names have now become household words, have received the prompt and plentiful financial support which has enabled them to inaugurate undertakings of exceptional magnitude, even in this era of tremendous monetary organizations. And, on the other hand, we have seen, in the numerous financial and engineering failures inseparable from such rapid development, the natural results of a too implicit faith in electrical omnipotence.

It is not to be wondered at that conservative engineers have been slow to adopt this new and mighty agent in the solution of extensive problems, and under circumstances where a single failure means not only a greater or less financial sacrifice, but the loss, in a greater or less degree, of professional reputation.

The mechanical engineer, while recognizing the fact that thousands of horse power are to-day transmitted by electrical means, from running the lathe in a dentist's office to the operation of a fifty-ton traveling crane; from passing a cooling draught of air through a sick chamber to printing the plethoric sheets of our daily papers, hesitates nevertheless, before placing reliance upon a system which has undeniably had its failures.

The mining engineer looks with interest upon the statement that 258 electric roads in the United States alone, with 1,927.26 miles of track and 3,024 cars are in daily service or under construction, and then compares the demands of street service with those found in mining practice, looking meanwhile for practical suggestions from those who have "been there" and can hold up a warning or beckoning finger to the traveler in this unfrequented path. It is the object of this paper to present briefly some of the work already done toward the application of electrical apparatus to mining processes, as well as to embody some practical suggestions and statements from those who have had personal experience in the operation of such apparatus.

A number of electric mining plants in actual operation were described by Mr. Spaulding. Of these the one running a 40 h. p. motor at Erie colliery, near Scranton, Pa., will serve as an example:

The power plant consists of a standard Armington & Sims engine capable of developing 60 h. p., and a 50 h. p. Thomson-Houston generator wound for a current of 220 volts potential, and the necessary appliances for its operation. The engine and dynamo room at the top of the shaft are in charge of the engineer and assistant, who operate the other mining machinery.

From the dynamo to the foot of the shaft the current is conducted by No. 0 Clark wires, inclosed in gas pipes to protect them from damage. From the bottom of the shaft the wires are carried overhead, about twelve inches outside of the low rail of each track, and are suspended from an insulator specially designed for this class of work.

Wherever turnouts occur frogs are used, the conductors being soldered to them in the same manner as when used for street railway work. Connections from the mains to the overhead conductor are made at suitable intervals, and a portion of the current is utilized for lighting purposes, two 110-volt lamps being placed in series. There are fifty of these lamps—eight at the foot of the shaft, two in the pumping-room, four in the blacksmith shop and two in the slope-room: the remainder being distributed along the gangway.

The rails are used as conductors for the return current, copper end-connections effecting a complete metallic circuit. In adapting the tracks to the electric system it was found necessary to make a few changes to accommodate the increased output. The shaft sidings will accommodate seventy loaded cars and fifty empties, whereas before they had a capacity for but fifteen on each side.

The locomotive is of 3-foot gauge, and has a length over all of 9 feet 7 inches, a width of 5 feet 3 inches, and height of 5 feet 6 inches. The weight of the locomotive is 10,500 pounds, to which 1,800 pounds has been added to increase traction. The motor employed is of the type "G" railway motor of 40 h. p. The locomotive is run by one man, who is assisted by a boy in making up the trains and turning the switches. It displaces seven mules and three drivers. During a period of eleven and a half days the average number of cars delivered at the shaft bottom by the locomotive was 559.5 against 526.95 per day delivered by mule haulage, much time being consumed by waiting at the bottom of the shaft for empty cars. Thus far the locomotive has shown that it will increase the daily output to 700 cars per day.

* Abstract of a paper read at the New York meeting of the British Iron and Steel Institute, Sept. 29, 1890.

Electric Welding.*

BY PROF. ELIHU THOMSON.

In this art, the foundation experiments were made about four years ago. The author had the pleasure of describing some of their results, particularly relative to electric welding, in a paper written in the latter part of the year 1886. The appearance of that paper aroused a considerable interest in the subject, which has continued from that time, and it is curious to note how it has caused the revival of early attempts to use the electric arc in metal welding or working, sometimes in conjunction with a magnet for displacing the arc and converting it into a blowpipe of great intensity, the latter being a procedure due, it is believed, to Wiedermann, in the early days of the production of electric arcs from dynamo machines.

The operations with which this paper deals are those in which the heating effect of electric currents traversing a solid metal conductor gradually brings the metal to the working temperature. This temperature is, in the case of easily fusible metals, much below a red heat, and is hence unattended with luminous effects which, however, appear in the case of metals softened or fused with greater difficulty.

It is proper here to correct an impression which has gained some currency, namely, that it is the extra resistance caused by the break or limited contact between the meeting portions of metal which gives rise to the heating in electric welding. While this limitation of contact surface undoubtedly hastens the heating at the joint, it is nevertheless a fact that a solid bar, joining the clamps of an electric welding machine, will be heated between those clamps to welding temperature, and may be upset by the approach of the clamps one toward the other. Indeed, this process is actually employed to upset collars on shafts, or to set or fasten in place, by a sort of riveting action, collars which have been placed as rings, more or less closely fitting, upon a bar or shaft. The real cause of the concentration of the heating effect at the joint, or between the clamps, is the relatively greater conductivity of other portions of the welding circuit, which circuit is usually composed of massive copper conductors, kept cool, in the case of large work, by circulation of water.

By thus keeping the clamps cool, as well as the conductor in which the welding currents are generated, their conductivity is preserved from running down and there follows a greater accentuation of heating effect at the joint, with the added result of a considerable saving in the electrical energy required to do the work.

The apparatus first used by the author consisted of an alternating current dynamo, feeding a comparatively high potential current to the primary coil of an induction coil or transformer, the secondary of which was made so large in section, and so short in length, as to supply to the work currents not exceeding two or three volts and of very large volume or rate of flow. The welding clamps were attached to the secondary terminals. The first type of apparatus has survived to the present day, and most of the apparatus is constructed on that principle, the secondary coil usually consisting of a single turn only. Other forms of apparatus, such as dynamos constructed to yield alternating currents direct from the armature to the welding clamps are used to a limited extent. While currents of one direction are quite suitable for electric welding, no special apparatus has been constructed for using them. Currents from storage batteries are quite suitable for the purpose, but the batteries should be constructed to stand very great rapidity of discharge, otherwise they become very cumbersome and difficult of application.

The practical results are not very different whether continuous currents or alternating currents are used, though it is to be noticed that in the discussion of Sir Frederick Bramwell's paper the actions of the two classes of currents were [illegible] of theoretically, to some extent, as different. It has b[illegible] shown that in conductors of large section the tendency of alternating currents is to keep to the surface of the conductor or to flow in the part of it furthest away from its centre. This is undoubtedly true as a tendency, but how far this tendency will be allowed to develop itself will depend on the drop of potential in a given length of conductor, a circumstance which appears to have been overlooked in many of the discussions of this interesting question. In other words, if the fall of potential, as in welding, is, say, two volts in two inches of length of the bar welded or worked, the density of current will be great, even in the centre of the section of the bar, but, of course, much greater near the exterior. But the heating effect also requires to be greater near the exterior, on account of radiation taking place at the outside surface. The practical result may easily be that there is really a uniform heating effect throughout the section of the bar; and without doubt the conditions could be selected to secure such a result.

In welding the ends of two bars, however, they are frequently rounded, and at the start meet only in the centre. In such cases, whether the current be alternating or continuous, the heating effect begins at the centre. A curious fact may here be mentioned. It is found that the distribution of the alternating current may easily be controlled by increase or decrease of self-induction at various parts of the section of the bar by the proximity of magnetizable iron masses.

The behavior of copper in welding by the electric current may be noted. It is an example of metal of very high conductivity for heat and for current. Naturally, to weld it electrically, the current strength required will be much greater for a given section than for metals of smaller conductivity. The heat produced escapes rapidly by conduction, and the low resistance of the metal requires a great current to be passed to cause it to heat. This is compensated for, in large part, by the fact that the copper requires a very low potential, or E. M. F.—less than a volt across the joint. The rate of energy consumption being the product of the current used by its electromotive force, and the total energy consumed being the product of this by the time, it will be seen that if a copper weld be made in a short time the losses by conduction and radiation from the joint can be kept down to a moderate percentage of the total energy.

A peculiarity of the electric welding process, and one which renders it capable of forming joints, even where metals may be coated with oxides infusible at the temperature of fusion of the metals themselves, is the expulsive power exerted to remove metal sidewise from the joint, and thus bring unoxidized, clean surfaces into contact at fusing temperatures. It is this fact which more than any other accounts for the universal applicability of the process to metals and alloys.

An important matter which may be mentioned in this connection is the facility with which the milder grades of steel may be manipulated in the welding by electricity. The advantage of the superior strength of the steel over puddled iron may thus be secured, which allows the use of a cheaper material, and less of it for a given strength. This remark applies forcibly to chain-making, in which the substitution of low steels for iron secures the double advantage mentioned, with the other advantages of the electric process over the ordinary ways of working. Considerable attention has therefore been given to the development of machinery for chain work, and a small working apparatus has even been made which takes a wire from a reel and turns out lengths of chain with electrically welded links; the operation being automatic throughout. A curious feature of electric welding work is that two or more welds may be simultaneously made in parallel. This fact is utilized in chain-making, where two welds, one for each side of a link, are made simultaneously. There are not yet in industrial operation any chain machines using the electric process. This step, however, is reserved for the near future. A special heavy chain machine will soon be completed.

Before closing this brief review of some of the phases of electric metal work reference may be had to the subject of economy in the work done, and to the power required. In the first place, the conditions vary so greatly that no general statement can be made; but when it is remembered that for making steam waste gases from operations requiring high temperatures are still hot enough, and that the nature of the electric current enables high temperature to be secured from power developed from steam at comparatively low temperatures, it is easily seen that in many cases of heavy metal working power for welding is already at hand, just as power for hammering in heavy forging is obtained in many cases from the waste gases of forges. Again, by the electric process the large water powers can

* Abstract of a paper read at the New York meeting of the British Iron and Steel Institute, Oct. 3, 1890.

be turned to account in metal working, and places where fuel is dear and water power plentiful may in future take positions of importance with respect to certain varieties of such work.

Furthermore, where steam is generated for the express purpose of welding and working metals by electricity, the localization of the heat to the exact point required, as compared with heating a considerable length or mass in the fire, with the loss of heat involved in so doing, may offset the heavy losses in the generation of power from steam. It is readily seen that the economy of heating to high temperatures in the fire must fall as the temperature of the metal rises, the temperature difference between that which gives heat and that which receives it becoming less and less. In the electric process the reverse is true, aside from increased loss by radiation and conduction as the temperature rises. During heating, the increasing temperature of the metal in most cases adds greatly to its resistance, and this in turn increases the electrical economy of the plant, or increases the proportion of the electrical energy converted into heat in the work itself.

Considered in relation to automatic character, range of adaptability, the convenience and cleanly nature of the work, the perfect control of temperature secured, and the uniformity of result, the electric welding and metal working processes are decided advances over the prior art, and seemed destined to a wide application.

The Ball & Norton "Monarch" Magnetic Separator.*

BY C. M. BALL.

This machine is the joint invention of Mr. Sheldon Norton, of Hokendauqua, Pa., and the writer, and has been patented in the United States, Canada, and other countries. Of the accompanying illustrations, Fig. 1 represents a longitudinal vertical section of the perfected Monarch ore separator, adapted for separating fine ore, and Fig. 2 the same, adapted for cobbing ore of the size of stove or chestnut coal. The two designs are identical in principle, and vary from each other in minor details only.

The apparatus consists of a partially closed chest, having an opening at *f*, from the feed-hopper *h*, through which the ore is delivered to the machine from an ore pocket or storage bin provided with means for regulating the flow of ore, so that when the machine is in operation the hopper is kept always full. Other openings are provided for the discharge, at *t*, of tailings; at *m*, of middlings; and at *c*, of concentrates; also, at *e*, for allowing free ingress of air to the chest at that point, and at *s*, where a powerful exhaust-fan is connected. The openings at *t* and *m* are kept sealed against ingress of air at those points by means of the hinged and weighted valves, *v*, *v*, which discharge the products from the hoppers *p* and *k* continuously, and in the same proportion as received from above, when a sufficient weight has accumulated upon the inside to cause the contents of the hoppers to leak by the valves.

The machine is also provided, as shown, with two drums, Nos. 1 and 2, turning upon the shafts, *i* and *j*. These shafts, together with the magnets *a* and *b*, which they also

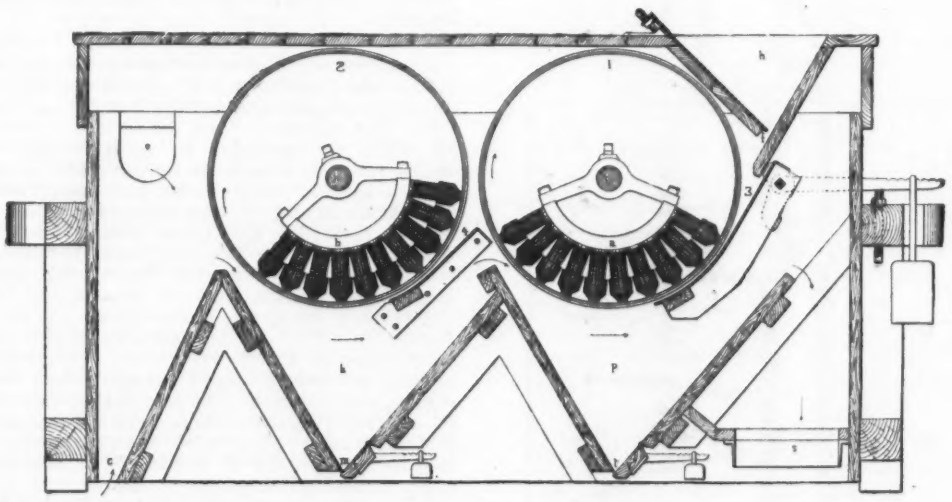


FIG. 1.—MONARCH SEPARATOR FOR FINE ORE, LONGITUDINAL SECTION.

serve to support, stand still, while the drums may be rapidly revolved around the magnets and out of contact therewith.

It will be noticed that the magnet occupies a section of the drum, the proportions being such that, approximately, one-third of the periphery of the drum is within the influence of the magnetic field, while the upper two-thirds is outside of the field and removed from the magnetic influence. The magnet is so constructed as to present a series of poles of alternately opposite polarity near the inner surface of the drum. In accordance with the well-known phenomena of magnetic attraction, which in the case of powerful magnets is exerted at a considerable distance from the magnetic poles, any magnetizable matter brought near the outer surface of the drum, within the arc covered by the magnet, will be powerfully attracted and drawn into firm contact with the outer surface of the drum. These drums are composed of a non-metallic and neutral material, such as wood, paper, etc., and they turn in the direction indicated by the arrows near the top of the drums.

Just below the feed-hopper an apron of neutral metal, No. 3, is arranged, curving downward and forward in the direction of the rotation of the drum, its lower portion describing a short arc concentric to the surface of the drum. This serves as a chute to direct the stream of ore falling from the feed-hopper within the influence of the first two or three poles of the magnet. A similar but somewhat shorter apron, No. 4, is arranged in like relation to the second drum and magnet, *b*.

Attention is called to the provisions for applying and directing the air current, which fulfills an important function in the process of separating ore as developed in this apparatus. The air may enter freely at the openings *c* and *e*, and is drawn through and out of the chest by the action of a powerful exhaust fan connected at *s*. The air which passes through the chest containing the drums and magnets must, of necessity, follow the course indicated by the arrows in the space below the drums.

When the machine is put in operation the magnets are excited, the drums are revolved in the direction before indicated, the air-current is established through the machine in a direction opposite to that of the rotation of the drums, and ore is supplied through the feed-hopper, which is kept always full. The ore passes down the chute under the first drum, and as soon as it comes within the influence of the magnet the magnetizable portions are drawn into contact with the drum, and through friction upon its surface take on the forward movement of the drum. At this stage, a curious and important result takes place. In accordance with the well-known laws of magnetic induction, a particle of iron brought near a magnet itself becomes a magnet by induction, and the magnetic force tends to bring the longer axis of this induced magnet into a position as nearly as possible parallel to the direction of the magnetic force. So a single particle, or many particles, brought near one pole of a magnet stand on end, as it were; and, in the case of many particles simultaneously influenced by the same pole, they form tufts standing out from the pole, their outer ends repelling each other, but all pointing in the direction of the lines of force toward some focus of opposite magnetic polarity. In conformity with this law, the particles of ore in contact with the drum opposite one of the poles of the magnet stand on end, forming tufts, spreading away from each other at their outer ends. As they are drawn along, however, by friction against the moving drum, when they get to a point midway between two poles they lie down flat against the surface of the drum, and, as they are drawn still further along, they again stand on end—but this time the other end out. So, in passing through the magnetic field, they are tumbled end over end as many times as there are poles in the field. The result is, that every time they are reversed in position opportunity is afforded for any non-magnetic particles of gangue, which may have been entangled with the ore, to fall away from the tufts of magnetite; and this result is still further facilitated by the centrifugal tendency and by the counter current of air.

When the ore reaches the limit of the arc covered by the magnetic field it is no longer attracted, and takes on a tangential movement, which carries it away from the drum. It has now, however, passed the edge of the second apron, and, on leaving the first drum, comes within the influence of the magnet of the second drum, where

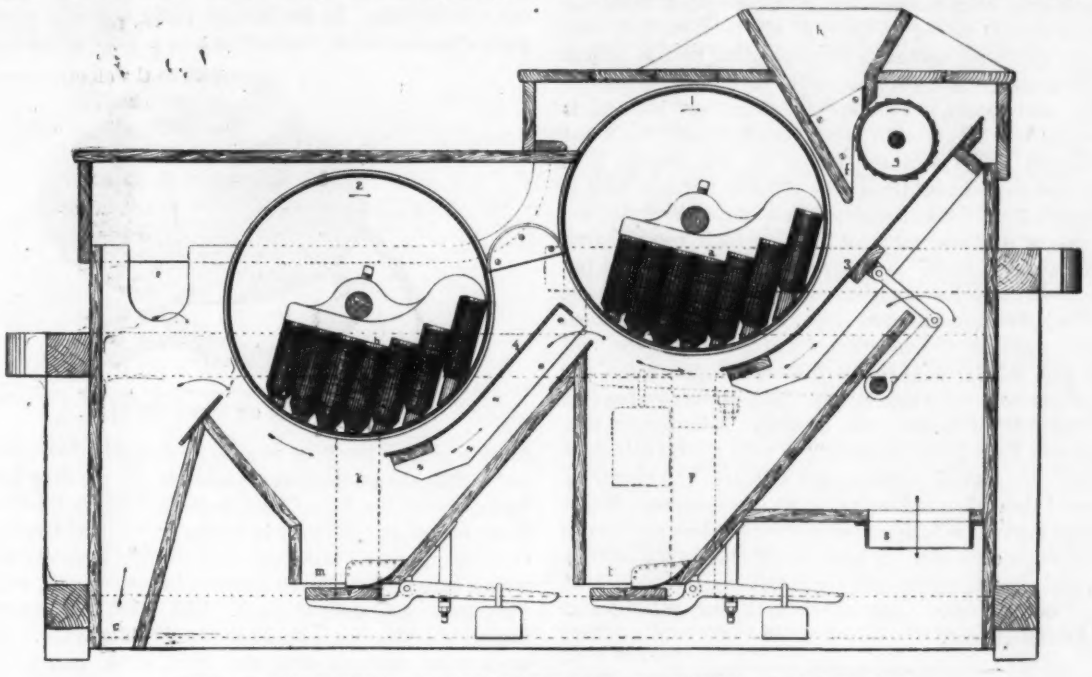


FIG. 2.—MONARCH SEPARATOR FOR COBBING LARGE ORE.

similar operations are repeated, a portion being finally discharged as concentrate at *c*, the function of the second drum and magnet being to differentiate the product from the first drum into two portions, which may be conveniently designated as middlings, discharged at *m*, and concentrate discharged at *c*. The middlings consist of particles of ore with adhering portions of gangue, which may require a little finer crushing to effect their mechanical liberation; or they may consist in part of iron compounds having a smaller degree of magnetic susceptibility than the pure magnetite. The separation of the middlings from the mass delivered to the second drum may be effected in two ways: If the drums have the same speed of rotation, a weaker magnetism in the second magnet will allow these less magnetic particles to drop away; or, if the magnets have approximated the same force in the two drums, a higher speed of rotation of the second drum will throw these particles off by reason of the centrifugal force overpowering the centripetal magnetic attraction, the magnet having the smallest influence upon the leaner portions of the mass.

The peculiar action of the ore in passing through the complex or multipolar magnetic field has already been described. Upon the mode of arrangement of the poles the efficiency of the apparatus largely depends. In this machine the magnetism of the field of attraction performs a two-fold function, viz., to attract the magnetizable matter of the ore, and, as it is moved through the machine by friction upon the revolving drum, to turn it over and over so as to allow the gangue to fall away, and also to permit the air current to take effect on all sides of every particle of the ore.

If the importance of this operation is once recognized, it will be readily understood that there can be only one possible efficient arrangement of the poles, and that it is not a matter of indifference whether they conform to this or some other plan.

The positive character of the functions above enumerated renders it possible to make an effective separation under the conditions of a very heavy supply of ore to the machine. The easy working capacity of a machine having drums of 24 inches diameter and 24 inches working face is from 15 to 20 tons per hour of ore granulated to pass 16 to 20 mesh screens. The power required is from 1 to 1½ h. p. in electricity for each drum, and ½ to ¾ h. p. to drive the machine.

*Abstract of a paper read at the New York meeting of the American Institute of Mining Engineers, Sept. 29, 1890.

The Spectro-Lantern.

A year or so ago mention was made, says the London *Electrical Engineer*, of a novel and ingenious invention in optical telegraphy by Paul la Cour, of Denmark. The apparatus obtained a first-class medal at the Copenhagen exhibition, and at the time attracted considerable attention among scientific and practical circles. It has recently been perfected for actual working, and is made in lantern form by Messrs. Th. A. de Neergaard & Co., of Cophenhagen, under the name of the spectro-lantern, and is worthy of

serious attention by those who deal with telegraphic and maritime matters. The apparatus is intended to render practical a method of telegraphing direct by light in Morse signals. It depends for its action upon the fact that white light, consisting of the colors of the rainbow, can be cut up by prisms in a lantern into these colors, forming the well known bands of the spectrum. By a suitable and carefully arranged system of screens and prisms these luminous spectrum bands can be given a certain form, which may be made to correspond with the long and short dashes of the Morse code. When, therefore, the light from the lighthouse lantern is observed from a distance through a telescope fitted with a prism, the light appears to consist of these signals, and can be so read by an experienced Morse operator. For the sending of a connected telegram a movable disc is passed in front of the lantern, this disc being provided with openings corresponding to the letters of the telegram, which are thus read off on the telescope as Morse characters. The spectro-signaling lantern is intended for use between different vessels on the one hand and between ships and the shore on the other. It is already used experimentally in the Danish marine, and is made to give four distinct signs, which correspond to the flag signals of the International Code, which can also be employed at night time. A different kind of lantern to the above is the lantern having a strongly colored light suitable for harbor lights and on board ships. By placing the lantern in various positions, the various colors of the rainbow can be seen, and this light is easily distinguishable from the usual red, green, and white lights. The telescope for this form of lamp is, of course, not needed. A lantern of this type has now been in use for nearly a year at the principal entrance to the port of Aarhuus, in Denmark, and excellent testimonials have been given as to its advantages. When the spectro-lantern is fully developed it may be expected to come into extensive use. It requires no clockwork, rotary glasses, and similar costly and breakable apparatus which easily get out of order, but consists of only a lamp and strongly fixed glasses.

Opening of the A. B. C. Store.

The beautiful new store of the alphabetical firm at 18 Cortlandt street was formally opened on Monday, Oct. 6. During the previous week the proprietors had been busily engaged in fitting up and getting ready for the business, doing the preliminary hustling to get their hands in for the fray. They should be congratulated upon having gone through this stage of the operations with a most admirable degree of success, for they certainly have given evidence of aiming at the highest type of electrical supply house and hitting the mark. The quarters secured in the Telephone Building, centered as it is in the very midst of the electrical quarter, are admirably adapted for their business.

In addition to the regular fittings of a supply house, they have elegantly furnished offices, and a feature that immediately strikes the visitor is a room specially fitted for the convenience of visiting electrical friends, a sort of headquarters where the wayfaring electrician may meet the kindly hospitality that Messrs. Alexander, Barney & Chapin know so well how to extend.

The firm opens with a remarkably diversified line of electrical supplies, and they are ready to supply anything, from a binding post to a million feet of cable. They are special agents for J. W. Queen & Co.'s well known testing apparatus, and one of the front windows is filled with a beautiful display of these instruments. They have secured a large number of special agencies; among them those of the Crosby batteries, McCreary shades and the Safety, American, and Grimshaw wires and cables.

All day long, Monday, the new store was the gathering place of pretty nearly the entire New York electrical fraternity, meeting there to inspect the admirable fittings and to extend the most cordial congratulations and best wishes to the alphabetical firm, than whom there is probably no trio of electricians better known throughout the country. The long connection of Mr. Alexander with electric lighting interests, and of Gen. Barney with telephone work, has given them a very wide acquaintance and a host of friends, who stand ready to greet them in their new departure and to wish them the most cordial and fullest measure of success that a new firm could desire.

In one of the rear offices an elegant lunch was spread, and the A-B-C-darians were most active in guiding their friends to the festive board. The occasion was a very pleasant one, marking, as it did, both the inauguration of what is most sincerely to be hoped will be a great and prosperous business, and also the friendly interest of the whole electrical fraternity in the genial trio who have the business in charge.

A very large proportion of the prominent members of electrical professions and trades were there to greet the new enterprise. Among the throng of guests were the following:

O. E. Madden, J. W. Sands, D. C. Cox, F. W. Harrington, Jas. P. McQuaide, E. G. Hawthorne, E. V. Baillard, W. A. Vail, Theo. Moss, Geo. M. Phelps, W. T. Hunt, F. H. Hayward, Jas. A. Taylor, F. B. Alexander, Allen R. Foote, B. F. Hamilton, H. D. Stanley, R. Stewart, Jean A. Wetmore, T. C. Martin, C. R. Truax, F. Jarvis Patten, C. G. Perkins, Dr. A. F. Mason, T. McCoubrey, Chas. W. Price, Lieut. B. A. Fiske, Frank E. Knight, A. H. Patterson, O. W. Leonard, Clarence E. Stump, Thomas R. Taltavall, W. H. Stanley, George Worthington, A. S. Hibbert, J. G. Carty, J. H. Cahill, S. S. Wheeler, W. H. Fleming, J. R. Weeks, and hosts of others besides, who added their universal good wishes that the firm of Alexander, Barney & Chapin may take the high place it deserves in the enormous electrical trade, that is certain to grow even faster than the most imaginative prophet could predict.

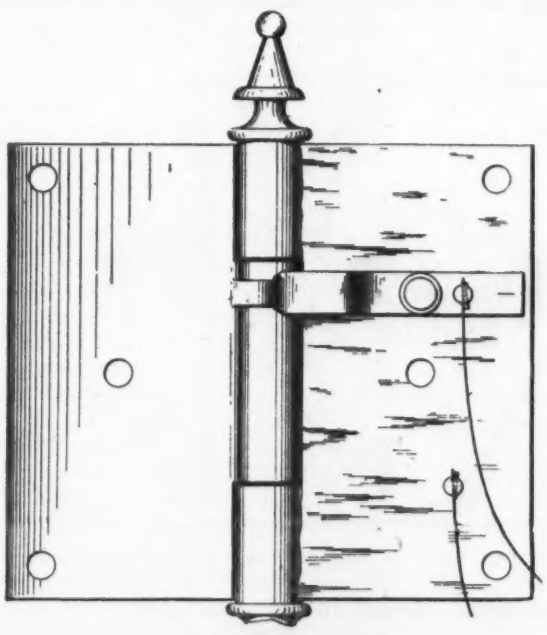
An Improved Push-Button.

It would seem that so simple a thing as a push-button leaves little room for improvement or change, but this is not wholly true. In the case of pushes used in connection with a wall or floor connection and a flexible cord, the extension part of the floor push is now considered very essential. Still the push-button which is in use may be on the table, or on the lap of the hostess, or very likely on the floor, unless special care is taken in looking after it. Mr. C. G. Armstrong, however, has designed an attachment which is to be considered quite an improvement, as it holds the push in any desired place. The Great Western Electric Supply Company is putting it upon the market. It is evident from the cut that the new push can readily be slipped on the edge of the table, or on one of the side panels, or even on a chair. Whether the push is uppermost or is concealed by being turned downward, it is always just where it is put. Any style of push-button can be furnished with this improvement.

New Form of Push Button.

Circuit Closer for Burglar Alarms.

We show herewith a very neat circuit closer for burglar alarms. Its feature most especially worthy of commendation is its extreme simplicity. It is intended for use on the class of burglar alarms which operate on open circuit. The contact device is applied directly to the hinge of the door and consists of a spring provided with an electric contact placed on the inner side of one leaf of the hinge and insulated from it by any suitable means. The point of this spring, as will be seen from the cut, projects beyond the leaf, so as to bear upon the cylindrical shank and the opposite leaf. Into this a small plug of hard rubber is inserted in such a position that when the door is fully closed and the leaves folded back upon each other the edge of the plug will just raise the spring out of contact with either leaf. On opening the door even a very small amount the spring drops down upon the shank of the hinge and makes contact, sliding over its surface as the door opens. The circuit is then from the contact on the spring through the spring and the body of the hinge to a second contact placed at any convenient point upon it. The result of this arrangement is a very certain closure of the circuit on the least opening of the door. The rubbing contact of the spring insures good electrical connection. The device has been recently patented by Mr. W. M. Bleakley, of Verplanck, N. Y., and is certainly a very convenient addition to an open circuit burglar alarm system. The good contact secured by this arrangement removes one of the objections to the open circuit system.



A Burglar Alarm Circuit Closer.

Earthquakes in Connection with Electric and Magnetic Phenomena.*

BY JOHN MILNE, F. R. S.

The only paper which has hitherto been brought to the notice of the Seismological Society of Japan treating of the relationship of earthquakes, earth currents and magnetic phenomena is the contribution by Professor R. Shida on "Earth Currents" (Trans. Seis. Soc., Vol. IX., Pt. 1). In the following pages Professor Shida's examples have been amplified, and to them many instances where electrical and magnetical phenomena have accompanied volcanic or seismic disturbances have been added. The object of this paper is to draw attention to a variety of observations which require amplification, and to express the hope that the systematic study of such observations may lead to the explanation of several phenomena which at present are not understood.

EXAMPLES OF ELECTRIC PHENOMENA.

From the observations on the lightning flashes playing in and around the column of ashes which accompany volcanic outbursts, and from the different investigations of Palmieri upon the slopes of Vesuvius, we know that at the time of a volcanic eruption the atmosphere becomes highly charged with electricity. One explanation for these phenomena is that the high pressure steam escaping from the crater is playing the part of the steam in a hydro-electric machine, the action being intensified by the friction of the heated solid particles against each other during their repeated ejection. The observations suggest that there may possible be some connection between earthquakes and resultant electrical phenomena. At the time of earthquakes it has often happened that the air has been found to be in a very electric state. For example, during the earthquake of 1808, in Piedmont, Fuchs tells us that such a condition was observed. Humboldt observed that during the earthquake of Cumana the electroscope quickly showed the presence of electricity in the atmosphere. A belief in South America is that electric discharges in the atmosphere and earthquakes are in inverse proportion to each other. The Mississippi and Ohio earthquakes of 1812 are said to have corroborated such an opinion.

Luminous appearances in the heavens are often mentioned in the records of earthquakes, as for instance at the time of the Lisbon earthquake in 1755, and that of Catania in 1693. In 1805 at Naples fire balls were observed about the time of the first shock. As seen from the sea, clear rays of light appeared to discharge themselves from the tops of the highest houses. These appearances, which are usually considered as electrical phenomena, are extremely numerous in the records of earthquakes. Just before the earthquake of New England, in 1727, flashes of lightning were seen (Phil. Trans., XXXIX.). Again before the earthquake in Sicilia (Jan. 11, 1692–3), a great light like a fire is said to have been observed in the sky (Phil. Trans., XVIII.).

A letter from Mr. Thomas Henry, F. R. S., describing the earthquake felt at Manchester (Sept. 14, 1777), speaks of his wife and others receiving in various parts of their bodies shocks similar to electrical shocks. Subsequent to the shock many people complained of nervous pains and hysteric affections similar to those who have been strongly electrified. Perhaps fright might have contributed to produce some of these effects (Phil. Trans., LXVIII., p. 221).

Schmidt says the maximum frequency of electric phenomena occurs in the middle of October or a few days later, and the minimum about the first week in March. If we refer to Schmidt's conclusion respecting the periodicity of earthquakes, we shall see, as he points out, that the maximum of earthquakes and the electric storms occur at periods but little different. To put the matter more generally, we find the greatest intensity of atmospheric electricity in winter, which is the season when earthquakes are most frequent.

EARTHQUAKES AND EARTH CURRENTS.

Attention was drawn to the connection between earthquakes and earth currents by Professor W. E. Ayrton in a communication to the Asiatic Society of Bengal in June, 1871, who observed that the Indian earthquake of Dec. 15, 1872, was preceded by such strong earth currents on the previous evening in the land lines from Valentia to London that, in order to send messages, it was necessary to loop the lines and in this way cause the current of one line to neutralize the other (Asiatic Society of Japan, April 25, 1877). The Egyptian earthquake (Jan. 12, 1873) was also preceded by strong earth currents. The Italian earthquake of March 17, 1875, was accompanied by great disturbances in the land lines. Again, in 1871, a few minutes before and after the earthquake of March 17, positive electrical currents were rushing towards England through the Anglo-American cables, which were broken near Trinity Bay, Newfoundland (C. F. Varley, *Nature*, 1871, April 20; also *Am. Jour. Sci.*, I., 1871, p. 472). As another example it may be mentioned that the earthquake of Ischia (1881) was signaled along some of the Mediterranean cables.

A remarkable example of the connection between earthquakes and the development of earth currents are the observations of M. Destieux, Chief of the Telegraph Bureau of Fort de France in Martinique, at the time of the earthquakes of September, 1875. Not only were the lines so strongly charged that they gave shocks to the hand, but the electric disturbances as indicated by the needle of a galvanometer in all cases seem to have preceded the shock by considerable intervals. Thus on Sept. 17 the galvanometer was greatly disturbed at 10:25 A. M., and at 10:52 there was a violent shock. At 12:19 the galvanometer was again disturbed. At 2:45 the electric disturbances were repeated, and at 3 P. M. came a strong shock. At 4 P. M. the disturbances were very great and at 6 o'clock came another shock. Similar observations were made on the succeeding day (*Compte Rendus*, LXXX., 1875, p. 693).

The results of some observations on this interesting subject, made by F. P. Crescimano, at Corleone, in Sicily, in 1876, were as follows: Two galvanometers were taken, and one was placed in a telegraphic circuit, while the other was placed in a circuit one pole of which led to a well, and the other to a hole in the ground. At the time of several small shocks the first of these instruments gave no indications. The well galvanometer gave some feeble movement magnetic of what was probably a positive current. Subsequently some strong shocks caused deviations of 8 degrees. On July 9, 1876, at 8:35 P. M., a shock occurred during the time that a dispatch was being sent to Palermo.

* An abstract from the Transactions of the Seismological Society of Japan, Vol. XV.

This was stopped, and the signal "Earthquake! Earthquake! Earthquake!" was sent. The operator, not understanding the signal, replied "Lift up the *tasto*, the current is too strong." This was raised, but the current was still too strong. The Palermo line was then thrown out of circuit and the Prizzi line put in. The galvanometer oscillated for 7 seconds and came to rest after 15 seconds. During the time that the Palermo line had been in circuit the needle of the galvanometer had made slight oscillations. A few minutes before the shock, the currents, which had previously been good, suddenly became bad. It is supposed that a positive current had suddenly struck the line (Rossi "Meteorologia Endogena," XI., pp. 86-87.)

CAUSES OF CURRENTS AND ELECTRICAL PHENOMENA.

In 1873, P. Serpieri observed that in many instances needles of galvanometers had been deflected a short time before the occurrence of earthquakes and that deflections were due to negative earth currents. In the *Revista Scientifica* 1874, p. 165, he offers the suggestion that the negative nature of the earth current may be due to the sudden development of a large quantity of steam which is electrically positive—the steam being the cause of the earthquake. In this article he quotes the interesting observation of Professor Domenico Ragona, who found that at the time of an earthquake there was a current from the earth passing through a galvanometer and a lightning-rod-like conductor to the atmosphere. To observe these currents, Professor Ragona suggests the use of a convenient apparatus, where the current passes by wire from the earth through a galvanometer to the flame of an oil or petroleum lamp, the base of which is isolated from the ground (*L'Elettricita*, 1887, No. 16, p. 241).

In connection with the observation made upon earth currents *Der Naturforscher*, VIII., p. 127, refers to the negative electricity of a hot spring in Baden, and in an article in *Jahrgung*, XX., No. 27, p. 243, makes special reference to the work done by Professor Luvini of Turin in endeavoring to obtain the assistance of telegraph operators in observing unusual disturbances in their instruments especially at or about the time of earthquakes.

One cause possibly producing earth currents would be the inrush of steam into fissures and cavities produced in rocks at the time or previous to the resulting crash which might be the cause of an earthquake. In addition to this, deep down in the earth we may conceive of the existence of intense chemical action caused by heated steam or molten matter acting on each other, and the materials they came in contact with giving rise to currents of considerable magnitude. The earth currents of an active volcano are a subject yet requiring investigation.

At the time I was observing the effects of artificial earthquake produced by the explosion of dynamite, I made the following experiments on earth currents: At distances of from 10 to 30 feet from the source of the explosion an iron bar was planted firmly in the ground. This was connected by a wire with a second bar also in the ground about a quarter of a mile distant at the other side of a deep moat, at a place where the vibration resulting from the explosion could not be perceived by carefully watching the surface of a dish of mercury. Near to this end of the circuit a Clark's differential galvanometer was introduced. The results obtained were that prior to the sound of the explosion and prior to the observation of any tremor in the mercury there was a strong deflection (10 to 40 degrees) of the galvanometer needle. The direction of this deflection was always the same. After deflection the needle of the galvanometer sometimes remained steady, sometimes, however, it very slowly (say in one hour) crept back to its normal position. When the first earth bar was moved to a point 150 feet distant from the explosion where the earth vibrations were feeble no deflection of the needle was observed.

The probable explanation of this experiment is that in consequence of the mechanical motion of the earth bar at the end of the line, its electric state, due to moisture and oxidation owing to a change in its contact with the earth, was altered. Certainly, similar effects could be produced by moving one of the bars or by hammering on the ground in its vicinity. The earth currents observed at the time of earthquakes may therefore, perhaps, be explained as being due to mechanical disturbances in the earth plates. So far as earth currents are concerned, when we consider the various manners in which they may be produced, the only point to be wondered at is that they have not been observed more frequently.

To give an explanation of the electrical phenomena which have been observed in the air is more difficult. In some cases they may only have been atmospheric phenomena which have accidentally synchronized in the time of their occurrence with earthquakes. Possibly perhaps sudden dislocations of strata may occasionally have caused sudden developments of statical electricity manifesting itself as luminous discharges in the air.

EARTHQUAKES AND MAGNETIC PHENOMENA.

On many occasions it has been observed that earthquakes have produced effects upon magnets or magnetic needles. In some cases the disturbances which have been noted may possibly have been due to mechanical action. About two hours before the destructive earthquake in 1855 the owner of a spectacle shop in Tokio observed that a magnet dropped some pieces of iron which had been attached to it. This observation led to the construction of a magnetic seismoscope described in a book called the "Ansei-Kembun-Roku."

Experiments made by Professors Ayrton and Perry, to determine whether a magnet at the time of an earthquake changes in its magnetic intensity, so far as they went showed the idea to be unfounded. In 1822 Arago and Biot made simultaneous observations of unusual movements in magnetometers at Paris, which coincided with the occurrence of slight shocks in Switzerland and the South of France. Humboldt, on Nov. 4, 1799, observed that in the earthquake of Cumana, although the magnetic declination and intensity were unaltered the dip was diminished 48 minutes. From this it subsequently slowly returned. The declination and the intensity of the earth's magnetism had, however, remained unchanged (Mal'et Reports of British Association, 1850). In October, 1802, the magnetic needle made at Lima 219 swings in 10 minutes, but after the earthquake only 213 swings. The inclination was also slightly altered before the disturbance being 9.59 degrees, and after only 9.12 degrees.

Prof. M. S. de Rossi gives several interesting examples of the coincidence between magnetic disturbance and earthquakes. On Nov. 1, 1755, on the authority of Sarti, it is stated that all magnets let their weights fall. The same year Bertrand, observing at Morat, near Neuchatel, says that at the moment of the earthquake the needle of a compass was seen to alter 25 degrees, and on the same day, at a place on the frontiers of Switzerland, some filings hanging from the point of a needle were observed to revolve against the needle; afterwards they returned to a vertical position. In 1869 an earthquake was felt at Rome, and it was observed that many horseshoe magnets dropped their armatures. Count Malvasia made a long series of observations on a small magnet holding light pieces of iron similar to an apparatus constructed by Bertelli. From the table of these observations it seems that the piece of iron often fell, sometimes with shocks and sometimes without them. Palmieri and Sacchi say that before the largest shocks at Melfi they observed changes in dip ("Meteorologica Endogena," Vol. I.). The results obtained by Malvasia appear to be very similar to the results said to have been shown by the magnetic seismoscope invented in Tokio.

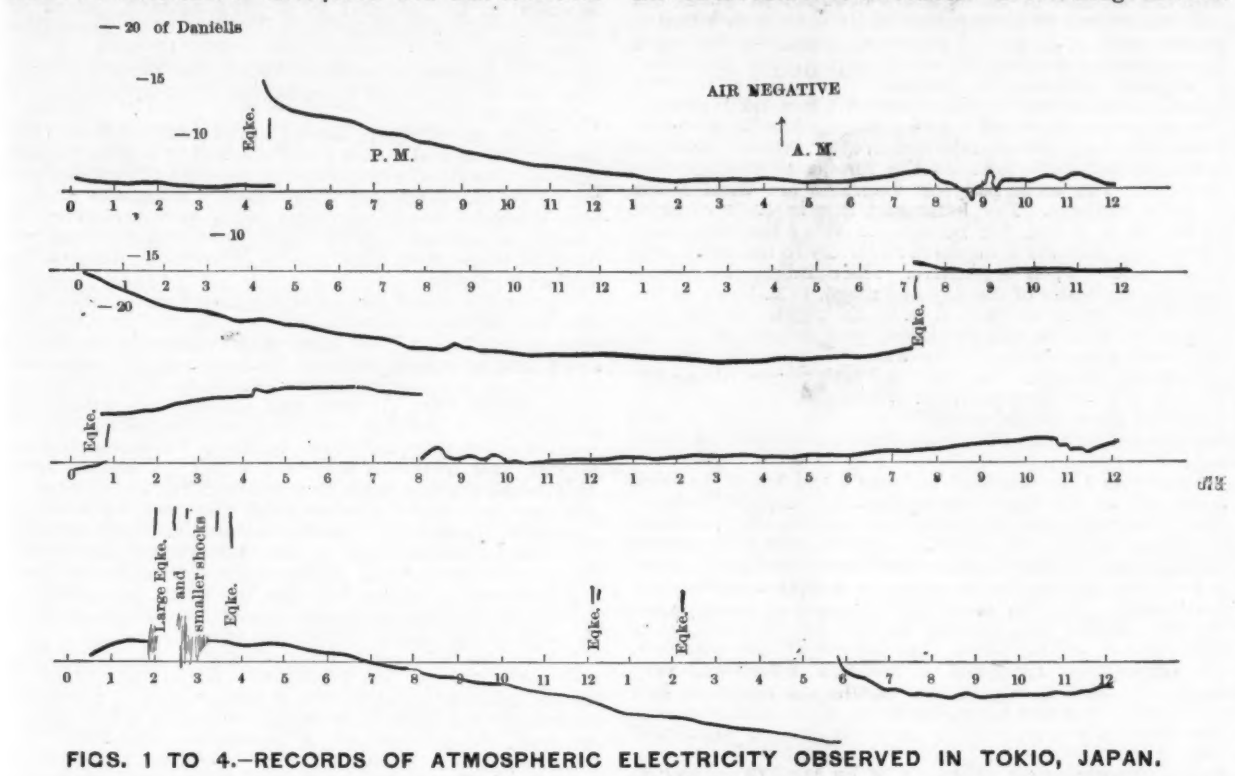
In THE ELECTRICAL WORLD, Nov. 30, 1889, we read that M. Mascart reports that M. Moureaux, who has charge of the magnetic observations at Saint Maur, has informed him that the magnetic curves for Oct. 25 show indications of disturbances similar to those which have previously been noticed on the occasion of earthquakes, etc. Since this the papers have announced an earthquake which caused considerable destruction at Gallipoli, and which, from all accounts, seems to have taken place at the moment when the magnetic disturbances were observed at Saint Maur. In this instance it would appear that the disturbance of the magnetic instruments could not be attributed to mechanical transmission of the shock.

As another example of coincidence in the occurrence of earthquakes and magnetic disturbance I give the following *précis* of a short article on earthquakes, published in the Annual of the National University of Colombia, 1870, translated by Mr. T. H. Wheeler, of the British Legation at Bogotá. After shortly stating and discussing Fabel's theory that earthquakes are caused by the action of the moon upon incandescent fluids in the interior of the earth, causing "seismic tides," the author mentions, in contradiction to this theory, the fact, of which he presumes that Fabel was ignorant, that none of the South American volcanoes throw out lava, but only calcined trachytic rocks, pumice stone, water, and enormous quantities of carbonic acid gas. These volcanoes, therefore, cannot be fed from the same sources as those in Europe, which eject lava, and the incandescent fluid existing in the interior of the earth cannot be one continuous mass; the tides caused by the action of the moon upon such fluids cannot therefore account for the production of earthquakes or of the eruptions of volcanoes.

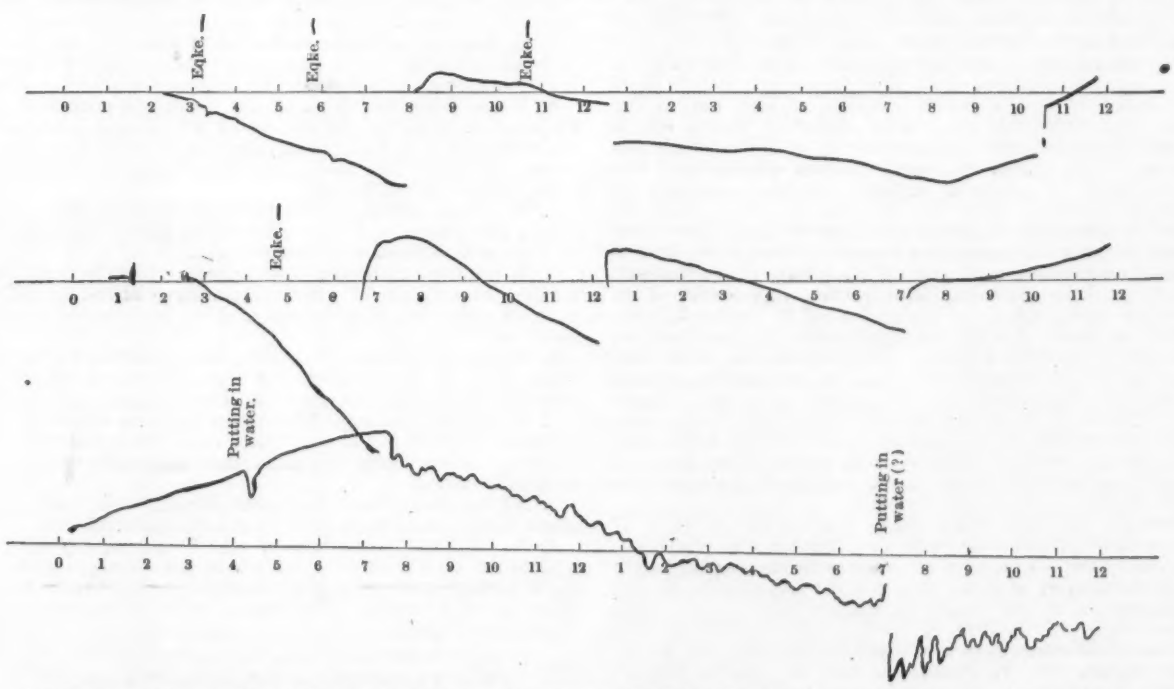
The author then proceeds to discuss a theory of magnetic currents as a probable cause of certain forms of earthquakes. During the earthquakes which occurred in Chili, Bolivia, Peru and Ecuador, successively on the 13th, 14th and 16th of August, 1868, a good declinometer placed on the top of a church in Quito, and constantly observed since the middle of June by a competent observer, indicated extraordinary deviations toward the east, the signs of strong magnetic tension. On the 15th, the eve of the catastrophe at Imbabura, it marked 4′.20″.60 morning magnetic amplitude, and 50′.30 evening amplitude, without diurnal period (*sin periodo diurno*), exceeding the ordinary deviation by 2′.2″. The night was very clear and fine. At 1:40 A. M. a subterraneous rumbling was heard, followed by a strong undulatory movement, which, running from southwest to northeast, culminated in Imbabura, expending its force upon the hills, plains and towns, precisely in the direction of the magnetic declination curve passing through Quito, as laid down in map 10 of the great atlas of Garnier.

The earthquake felt in Bogotá on the night of June 4, 1870, was also undulatory, and was propagated from southwest to northeast in a direction exactly contrary to that of the magnetic declination curve passing through Bogotá, and was preceded by magnetic disturbances analogous to those observed in Quito. The following is an account of the earthquake of June 4, 1870, at Bogotá by Señor José Maria Gonzales, the editor of the *Scientific Review* in that city:

On June 4, between 3 and 4 P. M., deafening subterraneous noises were heard, very prolonged and something like the sound of a distant waterfall. This, combined with continual agitations and considerable deviations of a very sensitive magnetic needle which was constantly observed, gave warning of the approach of an earthquake. And, in fact, at 9:20 P. M. a deviation of the needle of 0 degrees 15 minutes toward the east was observed, and at 9:40 P. M. a strong horizontal rectilinear shock was felt, the seismic wave moving from southwest to northeast. The concentrated seismic wave was felt during three seconds, and the retarded wave kept up an undulatory movement (only perceptible by the instruments) during 14 minutes 35 seconds. During the passage of the concentrated wave the magnetic



FIGS. 1 TO 4.—RECORDS OF ATMOSPHERIC ELECTRICITY OBSERVED IN TOKIO, JAPAN.



FIGS. 5 TO 7.—RECORDS OF ATMOSPHERIC ELECTRICITY OBSERVED IN TOKIO, JAPAN.

In THE ELECTRICAL WORLD, Nov. 30, 1889, we read that needle attained a maximum deviation of 0 degrees 45 minutes to the east, exhibiting at the same time a sharp trembling, which slowly decreased and terminated in 13 minutes and 55 seconds. The proper correction being made in the pendulum for the velocity attained, it appears that the shock lasted 14 minutes 3 seconds. From that time perfect calm continued until 2:10 A. M., when the magnetic needle showed a slight undulatory movement. At the same time a pendulum of 2 inches acquired a slight rotary movement in the form of an ellipse of great eccentricity, with the major axis in the direction north 35 degrees 30 minutes east. During this second shock, which lasted 10 minutes 15 seconds, the waves followed each other at intervals of 30 seconds approximately, and lasted from 2 to 3 seconds each. On June 5, at 10.35 P. M., a very slight undulatory movement was observed, only perceptible by the indications of a very sensitive instrument. It lasted 10 minutes 15 seconds. It was not continuous

like that which occurred at 2 A. M. on June 4, and caused no considerable deviations of the magnetic needle.

The greater number of earthquakes which have occurred in this part of America have taken place at the time of the equinoxes; that is, at the time when the thermo-magnetic currents are most powerful. This gives some reason for suspecting that they are the cause of those strong, undulatory earthquakes which extend over a large surface of the country, since the direction of these had nearly always been the same as that of the magnetic curves. This only applies to those shocks which are *strong* and extend over a *large* area, for the slight local shocks, not undulatory in their nature and not extending to any great distance, are caused by movements of the earth or rocks in the interior of the mountains; a great part of the Andes containing calcareous strata, and being therefore cavernous (as M. Boussingault has observed), are liable to subside.

Many instances where magnetic storms and earthquakes have occurred at or about the same time have been collected by Kreil (*Der Naturforscher*, No. 27, p. 242). On April 18, 1842, 10:09 A. M., Lamont observed a sudden change in the declinometer in Munich. At the same time Colla observed a similar disturbance in Parma, and during the same minute there was a severe earthquake in Greece (Lamont, "Astronomie und Erdmagnetismus," p. 277). A similar observation is noted in Poggendorff's "Annalen," Bd. CXV., p. 176. This occurred on Dec. 26, 1801, at 8 A. M., when instruments for declination, inclination, and for intensity showed unusual movements simultaneous with which there had been severe earthquakes in Greece.

At the Magnetical Observatory in Tokio, where magnetic elements have been automatically recorded for the past few years, there does not appear to have been disturbances at about the time of earthquakes more than those which may be accounted for as being due to mechanical movement. Such irregularities are most noticeable by the lines indicating variation in declination. They are occasionally noticed in the records for horizontal force, but hardly ever in the curves for dip, these latter parts of the instrument taking up less movement than that which records declination.

In *Nature* of March 3, 1887, Mr. G. M. Whipple, superintendent of the Kew Observatory, gives a copy of the diagram obtained from the bifilar magnetograph at his observatory, showing the movement produced by the Riviera earthquake of Feb. 26. The magnetograph disturbance occurred at 5:40 A. M. Similar disturbances were observed at Perpignan, Paris, and Lyons, and M. Mascart observes that these disturbances were simultaneous, and it was not therefore an oscillatory movement passing from point to point which had to be considered, but a phenomenon affecting a large area simultaneously.

The most carefully studied magnetical and electrical phenomena which have accompanied volcanic and seismic disturbances are those which occurred at the time of the eruption of Krakatoa on Aug. 27, 1883. The magnetical disturbance on this occasion passed from the east towards Europe, being recorded later and later as it progressed westward. Ordinary magnetic movements are almost simultaneously produced at different parts of the earth's surface. The stations at which observations were made were Zi-ka-wei, Colaba, Mauritius, Pawlowsk, Vienna, Kew, Stonyhurst, and Lisbon. The average values of travel were:

For declination	761 miles per hour.
For horizontal force	939 miles per hour.
For vertical force	927 miles per hour.
Final true mean	868 miles per hour.

At Batavia the magnetical disturbance was attributed to the magnetic iron contained in the rain of ashes (Report of the Krakatoa Committee of the Royal Society, 1888).

Whether we are to consider that there has been a relationship between seismic action and terrestrial magnetism definitely established is yet an open question. The observations so far as they have gone have, however, been sufficient to justify further research upon this subject. Rossi holds the opinion that the phenomena which have been observed are not purely mechanical, and that at the time of an earthquake there is an electrical action which more or less paralyzes a natural magnet. ("Meteorologia Endogena," Vol. I., p. 83, etc.) If we admit that the earthquakes of certain regions are the outcome of volcanic energy, and at the same time bear in mind the intensely magnetic character of many lavas, the possibility of a connection between local variations in terrestrial magnetism and seismic phenomena is apparent. The lavas of the Hawaiian Islands affect the needle of an ordinary theodolite. In Iceland and in Japan I have picked up pieces of lava which will cause the needle of an ordinary compass to revolve. The surface soil of the latter country is saturated with grains of magnetite derived from the decompositions of volcanic rocks. Some of the volcanoes in Japan, like Mont Nuova in Italy, came into existence during the historical period, and with their origin, which was accompanied with seismic phenomena, it seems impossible that there should not have been enormous local changes in magnetic elements.

Not only have the effects visible to us on the surface of the earth to be considered when discussing this question, but the effects which take place beneath the surface, such as the formation of dykes and general alterations in the arrangement of the magnetic magma from which these dykes originate. Effects of cooling also might possibly produce slow changes in the magnetic intensity of a volcanic region. Dr. E. Naumann tells us that as you approach Ganjusan, a volcano in northern Japan, there is evidence of a change in declination which near the mountain amounts to 14 degrees, and that this change has taken place during the last 80 years (Trans. Seis. Soc. of Japan, Vol. VI.). If earthquakes are indicative of a change in the character or the position of a magnetic magma beneath the earth's crust, to seek for evidence showing that seismic phenomena are connected with magnetic variations is not unreasonable.

Since writing the first part of this paper, Mr. P. Mayet has called my attention to the following curious phenomena observed upon the Sonnblick, a mountain in the Austrian Alps 10,154 feet high (see *Die Gartenlaube*, No. 21,890, p. 35). At the meteorological station on this mountain Dr. Wilhelm Trabert observes that a storm is not heralded by dark clouds, thunder, and sultry weather. The warning of the coming storm is, however, given by a crackling in the telephone. This is sometimes quite loud. The passage of sparks between the plates of the lightning arrester and the ringing of the bell indicate that the telephone must be thrown out of circuit. When the storm comes sleet and hail strike the window and a lightning rod may be struck, and *when the lightning strikes the house it shakes as if in an earthquake.*

ATMOSPHERIC ELECTRICITY AND EARTHQUAKES OF TOKIO.

At the Imperial Meteorological Observatory in Tokio atmospheric electricity during the greater portion of the last two years has been automatically recorded by the photographic arrangements of Mascart. In this system the needle of an electrometer which has a bifilar suspension is kept at the potential of the atmosphere by connection with a water dropper, while the quadrants of the electrometer are kept at a constant potential by connection with 50 water Daniels.

Through the kindness of the director of the Observatory, Mr. Aral Ikuosuke, a few days ago a series of records extending over a period of 12 months were placed at my disposal for examination, which I have compared not only with the records of earthquakes obtained in Tokio, but with the records of earthquakes which have been noted in various parts of Japan. A glance at these records at once showed that at the time of certain earthquakes there was a change in potential, the air suddenly becoming electronegative--the mirror turning so quickly to a new position that its movement could not be photographically recorded. From the new position, however, after several hours it gradually fell back towards the line from which it had deviated. The accompanying diagrams are illustrations of these changes. The horizontal line in each of these figures is a datum for reference. When the diagram is above this the air is negative relatively to the earth, and where below it, it is positive. The numbers along these lines are the hours of the day and night, P. M. being to the left of the central line and A. M. to the right. If you discharge the electrometer by placing your finger on one of the connections leading to the water dropper the spot of light swings to zero. On removing your finger it quickly returns to its original position. Shaking the pipe with an insulated glass rod Mr. Outsuka, who is in charge of this department, informs me produces no effect upon the reading.

From Fig. 1 we see that between 3 and 5 P. M. on April 3 the air at the time of an earthquake suddenly became electro-negative, and the potential was not restored until 5 A. M. on April 4. A somewhat similar change is shown in Fig. 2 and in Fig. 3, but in Fig. 3 at about 8 P. M. there is a sudden change in an opposite direction without an earthquake. In Fig. 4, between 2 and 3 P. M., on April 18, the mirror was moving to and fro so quickly or else was so far displaced that no record was obtained. An earthquake happened at 2:07 P. M. which was very large, at 2:54 P. M. which was small, and again at 3:39 P. M. which was also large, but there is no reason to suppose that the ground was in constant motion during the time that the spot of light from the mirror failed to record. The displacement at about 6 A. M. on April 19, as well as those shown in Figs. 5 and 6, was not accompanied by earthquakes, although several earthquakes occurred upon the same days. Fig. 7 shows an irregular diagram of ordinary occurrence. From these few diagrams it would appear that certain earthquakes are accompanied by sudden changes in the diagrams, that other earthquakes occur within a few hours of such changes, and that similar changes may occur without earthquakes.

CONCLUSIONS RESPECTING THE TOKIO OBSERVATIONS.

Until further observations have been made the following conclusions must only be regarded as tentative. They are as follows :

1. If there is a strong disturbance shaking an area 60 or more miles in diameter, with Tokio near the centre, the air suddenly becomes strongly negative. This has occurred 10 times. To this rule there has been only one exception. There are two cases where the centre of the disturbances appears to have been 25 miles south of Tokio. These earthquakes have not always been accompanied by vertical motion, and they have occurred at different hours.

2. If there is a feeble disturbance only felt in Tokio, such disturbances have been 13 times accompanied with feeble electrical disturbances and 31 times without.

3. When Tokio has been at the southwest corner of an ellipse of disturbance, the centre of which may have been 15 to 20 miles to the northeast, there have been three cases when we have had electrical disturbance and 12 cases without such disturbances.

4. When the centre has been 50 or 60 miles northwest of Tokio, there have been two cases of electrical disturbance and 11 cases without such disturbance.

5. When the earthquake has shaken a narrow band extending from Tokio 30 miles north, there have been three cases of electrical disturbance and no instance of no disturbance.

6. When the centre of a disturbance has been 20 or 30 miles east of Tokio there has been one case of electrical disturbance and six cases with no disturbance.

7. When the centre of disturbance has been from 20 to 100 miles west of Tokio there have been three instances of electrical disturbance and three instances where there was no disturbance.

8. At the time of earthquakes in Japan, which did not reach Tokio, there have been no sudden disturbances.

9. In electrical disturbances which accompany earthquakes the air almost invariably becomes electro-negative, the potential suddenly rising sometimes as much as 30 volts. From this it is usually several hours before it returns to its normal condition.

The United States Telpherage Patent.

In the matter of the interference between the application of Rudolph H. Hunter, filed May 22, 1886, and the patent No. 305,194, to Fleeming Jenkin, granted Sept. 16, 1884, on application filed Feb. 1, 1883, the examiners-in-chief of the United States Patent Office have reversed the decision recently made by the examiner of interferences in favor of Hunter.

The claims in the patent in question are :

1st. In the herein described system of telpherage, the combination of a conductor divided into sections, switches, which normally bridge from one section to the other, traveling trains or vehicles, electric motors on the train or vehicles, by which they are driven, and devices operated by the trains or vehicles to move said switches successively and divert the current through the motors on said trains or vehicles, so that the motors are connected in series through the divided conductor.

2d. In a system of telpherage, the combination of an insulated suspended conductor, a source of electric energy therewith, a traversing train or vehicle sustained thereby and traveling thereon, and an electric motor upon said vehicle, supplied with electricity from said sustaining conductor.

In their decision the examiners say: "Jenkin has a domestic patent granted Sept. 16, 1884, prior to the application of Hunter. He also has an English patent which, by stipulation and in fact, is proof of the invention and patenting of this invention by him on Oct. 17, 1882. Hunter has no patent. His application for a patent was filed May 22, 1886.

"Hunter testifies to a conception of the invention in the year 1878, and produces as evidence that he possessed the invention prior to Oct. 17, 1882, his exhibit copy of drawing, 1879, and his exhibit drawings Nos. 1, 2, and 3. These are free-hand sketches with no mechanical details of construction, and with no attempt to display any mechanical construction. They represent in a diagrammatic manner an arrangement of electrical apparatus which plainly discloses a full conception in the mind of the drawer of them of the issues here in controversy. They do not disclose a completed invention, not being working machines ready for use, or used, one of which facts they must have then been in order to be potential to deprive Jenkin's patent of novelty. They established only the fact of a conception of the invention by Hunter prior to Oct. 17, 1882. It remains for Hunter to establish reasonable diligence from that date to the date of his reduction of his invention to a practical form.

"In this interference, Hunter's application opposes a domestic patent, and such a patent backed by a prior foreign patent. Reasonable diligence is a question of fact depending on the circumstances of each case. What was reasonable diligence in an applicant with actual reduction to practice as against a prior applicant without actual reduction to practice may not be reasonable diligence as against a patentee.

"Generally stated the facts herein indicating diligence are that Hunter did nothing more with his invention except to produce a few more sketch-drawings, exhibits 5 and 6, and an equally abstract illustrative model, all so far as this issue is concerned mere repetitions of his sketches made before Oct. 17, 1882, and showing no advance in adaptation or towards perfection until he reduced his invention to a practical form by filing his application on May 22, 1886, a lapse of three years and six months after Jenkin had the invention in practical form, and a lapse of one year and eight months after the issue of Jenkin's United States patent. He reduced the invention to practice after the declaration of this interference and nearly two years after the date of his application and more than five years after Jenkin had this invention in a practical form in his British patent, and more than three years after the issue of Jenkin's United States patent.

"When an inventor is proceeding with the adaptation and perfection of his invention without knowledge or notice, actual or constructive, of the presence of any other inventor in the field of invention which he is traversing, an easy, thoughtful pace is reasonable diligence. But where there is a patent for that invention, it is a public record and all persons are not only presumed to know its contents but are bound to take notice of them and of the rights and duties which they confer and enjoin.

"From Oct. 17, 1882, Hunter was required to evince the reasonable diligence of an inventor who knows of no competitor. But from Sept. 16, 1884, he had notice that another had secured the title to what he then regarded as his invention. Reasonable diligence on his part with such notice is that diligence which any owner of property must exercise when he discovers that another has taken possession of his property. Then nothing less than that immediate and energetic action which the nature of the case requires to regain possession of his property can be regarded as reasonable diligence.

"Under the circumstances of this case, the reduction to practice being, as he contends, beyond his power, the immediate filing of an application was clearly the remedy which it was necessary for him to adopt, in order to recover his property then in the possession of another inventor. The failure, for one year and eight months after the grant of Jenkin's United States patent, to file the application for the invention deprives him of that reasonable diligence which he should have exercised, in order to defeat Jenkin's patent.

"The drawings alone are not sufficient to defeat Jenkin's patent. His illustrative model is worth no more than his sketch-drawings. They must be followed up with reasonable diligence by other acts to adaptation and perfection of the invention.

"Considered as a whole, we are of opinion that Hunter has failed to make such a case as would defeat the patent to Jenkin for want of novelty. The decision of the examiner of interferences is reversed and priority awarded to Jenkin."

Special Correspondence.

NEW YORK NOTES.

OFFICE OF THE ELECTRICAL WORLD,
167-177 TIMES BUILDING, NEW YORK, Oct. 6, 1890.

To Run its Cars by Electricity.—The State Board of Railroad Commissioners of New York has granted the application of the Long Island City and Newtown Railroad Company for permission to change its motor power from horses to electricity.

Queen & Co.'s Testing Instruments are to be kept in stock in this city at the new store of Alexander, Barney & Chapin. A full line of ammeters, voltmeters, resistance boxes and electrical measuring instruments of every description will be kept on hand.

Crocker-Wheeler Motor on a Gatling Gun.—A trial was made recently of an electric motor of the Crocker-Wheeler type fitted to a Gatling gun as a substitute for a man in conducting the firing operations. The test was entirely satisfactory. A speed of 1,000 shots per minute was easily reached and maintained.

Mr. E. W. Hazazer, 35 Frankfort street, this city, has sold his interest in the firm of Hazazer & Stanley, retaining, however, the construction business of that firm, and will carry out all unfinished contracts which had been taken by the firm. Mr. Hazazer will continue in the construction business, and as this has been a large part of his work for 10 years, whatever contracts he takes will be intelligently carried out. His former work has been of a high character.

Mr. J. B. de Lery presented to the New York Electric Club at its dinner last week a beautiful floral design representing the tower which he is to erect in South Lakewood Park, the "electric city." The floral tower was seven feet high and three feet square at the base and modeled after the Eiffel tower of the Paris Exposition, and represented the "art," "science," "progress" and "industry" in the electrical trades. Mr. de Levy was highly complimented on his unique and handsome gift.

Lights Automatically Extinguished.—Jackson's store, on Broadway, lighted up the elegant show windows with 10 incan-

descent lights for the first time last week. The United States Electric Light Company put in the automatic clock and cut-out to extinguish the lights at midnight, or earlier if desired. The consumer was looking for just such an arrangement to save unnecessary burning of lamps and expense of metre. The number of show windows throughout the country, wired and fitted with incandescent lamps, which are not used on account of expense is very large. To such the automatic clock and cut-out will prove very useful, and is a source of profit to the electric light companies. W. H. Gordon & Co., 115 Broadway, this city, have taken the general agency for this apparatus.

Messrs. Hatzel & Buehler, of this city, are wiring Mr. Stone's residence on Fifth avenue, and installing a one horse power Detroit motor for Smidt & Berlin, opticians, an incandescent plant in the Crescent Iron Works, at Elizabethport, N. J., an incandescent plant in the U. S. Bank building, at 40 and 42 Broadway, this city, an incandescent plant at the Gerlach Hotel, and are remodeling the plant in the Barrington apartment house. This company is installing a very complete plant in the American Express Company's new building on Hudson, Jay and Staple streets, this city, to consist of two McIntoch & Seymour engines; two 600 light dynamos, compound wound for 110 volts, self regulating and self lubricating, with a commercial efficiency of 91 per cent.; two ammeters, one voltmeter, and one ground detector; 500 Sawyer-Man or other lamps; eight arc lamps for incandescent service; and three Detroit motors of 10, 15 and 20 h. p. W. T. H.

NEW ENGLAND NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
Room 8, Cook Building, cor. Franklin and Congress Sts.
BOSTON, Oct. 4, 1890.

Dividend.—The Thomson-Houston Electric Company has declared a dividend of $3.50 per share on preferred stock.

Mr. E. H. Cutler, treasurer and manager of the Elektron Manufacturing Company, of Brooklyn, N. Y., was in town this week.

Electric Light Plant Sold.—The Derby (Conn.) Rubber Company has bought the plant of the Electric Light Company at Shelton, and made arrangements to enlarge it.

The Rhode Island Electric Protective Association has a fine exhibit of its electrical specialties at Centennial Hall, Pawtucket, R. I., during the Cotton Centennial.

New Isolated Plant.—The new 500-light plant installed by the Standard Electric Company at Dizer's shoe factory, East Weymouth, Mass., is now in operation, and is giving good satisfaction.

The Holtzer-Cabot Electric Company will make a fine exhibit at the big Mechanics' Fair, which opened Oct. 1. A part of it will consist of fitting up a room with electroliers, electric lighting apparatus, etc.

Electric Light for the Navy Yard.—The officials at the Charlestown (Mass.) Navy Yard have petitioned the Navy Department for electric lights in the barracks, and in all probability they will be put in this month.

Massachusetts Institute of Technology.—The largest courses numerically this year will be those in electrical, civil and mechanical engineering, each of which will enroll more than 100 students, including both regulars and specials.

Electric Cars in Waltham, Mass.—After a series of vexatious delays, the Newton Street railroad started its cars over the Waltham end of the route last Sunday morning at 7 o'clock. Upward of 3,500 people availed themselves of an opportunity to try this new method of conveyance.

The Thomson Electric Welding Company has leased three complete machines to Mr. Edison for use at the Schenectady works in welding copper wire from No. 20 to one-half inch. It is reported that they will be delivered within 30 days, and are expected to make 3,000 welds per day.

The Tripp Manufacturing Company, of Boston, will be represented at the Street Railway Convention, to be held at Buffalo this month, and will have on exhibition a large model of its standard electric trucks, which are meeting with favor with the street railway companies. The model will be equipped with the Tripp antifriction journal bearings.

Electric Railway Opening at Salem.—The Naumkeag street railway, at Salem, Mass., last week formally opened its Peabody division under the electric system, and a party of 350 gentlemen, representing Peabody, Beverly, Wenham, Danvers, Marblehead and the city council of Salem, were taken over the line, and then to the Salem Electric Light Works, where the power generators were inspected. Cars were then taken to the Willows, where a dinner was served.

Sale of Thomson-Houston Stock.—Messrs. Lee, Higginson & Co., of Boston, have purchased for themselves 50,000 shares of Thomson-Houston stock at $50 per share. The Thomson-Houston Company have issued a circular to stockholders offering stockholders of record Oct. 3 the right to subscribe to 10,000 shares of common stock at 50, the subscriptions payable in cash on or before Oct. 15. S. Endicott Peabody, president of the American Loan and Trust Company, and T. Jefferson Coolidge, Jr., president of the Old Colony Trust Company, have been added to the Thomson-Houston board of directors.

A New Electrical Supply and Construction Company has been formed in Providence, R. I., under the name of Drake, Payson & Whittier. The members are well known to the trade and are Mr. John I. Drake of the Russell Mast Arm Company, Mr. S. R. Payson, for years identified with burglar alarm and general electrical work, and Mr. R. H. Whittier, formerly manager of the Rhode Island Telephone and Electric Company. They have opened new and commodious offices and supply rooms in the Aldrich Building, corner Washington and Eddy streets, occupying rooms 1 to 8. They have already secured the contract for the wiring and inside work of the new plant the Edison General Company is to installs and which includes the towns of Riverpoint, Clyde, Phœnix, Arctic, Centreville, Harris and Lippitt, using some 4,600 incandescent lights. The three-wire system will be used, and Armington & Simmgines will furnish the power. They have also contracted to install 50 lights for D. Wilcox & Co., jewellers; 150 lights for the Kendall Manufacturing Company, and 50 lights for John R. White & Son. L. H H.

PHILADELPHIA NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
31 CITY BUILDING, PHILADELPHIA, Oct. 4, 1890.

Lockhaven, Pa.—Through the influence of Senator Peale, the council of Lockhaven has granted Messrs. Bianchard & Schultz, of Philadelphia, the franchise for lighting the streets and dwellings with arc and incandescent lights.

The National Electric Company is constantly receiving orders and inquiries from all parts of the country for the Warrell patent fuse blocks, of which this company is the sole manufacturer. The company is also doing quite an extensive business in general construction work.

Messrs. J. W. Queen & Co. have received an order from the State School of Mines, of Golden, Colo., for a complete set of test instruments to be used in the school. They are making a specialty in ammeters and voltmeters, and have the reputation of making reliable goods.

Doylestown, Pa.—A committee of council have been sent to visit the various electric light plants in the vicinity of Philadelphia to ascertain the best system of lighting. They expressed themselves very much pleased with the Jenkintown plant, recently installed by C. M. Blanchard.

Mr. J. B. Baker, a graduate of the Massachusetts Institute of Technology, of Boston, has recently associated himself with Messrs. C. M. Blanchard and L. R. Schultz. Although a young man, Mr. Baker has already made quite a reputation in the technical branch of the business, and promises to be one of the best masters of his profession.

New Electric Railway.—Application is about to be made for a charter for the Reading, Shillington & Mornsville Electric Railroad. It will be five miles in length and will connect Mornsville, a flourishing manufacturing town of 1,200 inhabitants, with the county seat, passing also through Oakland, Shillington and Hendleton, all growing places. The capital stock is $50,000, divided into 1,000 shares of $50 each.

A Market House Plant.—The Philadelphia Market Company's new building, Thirtieth and Market streets, is being fitted with a 40-light alternating arc plant and 900 incandescents, running from three Westinghouse engines. The main market will be lighted by the arc lights, and the cold-storage rooms, sheds, vaults, etc., by the incandescent. This plant will probably be one of the most complete in all its details ever installed in this city.

The new incandescent plant at the clothing store of Jacob Reed's Sons, on Chestnut street, installed by the United States Electric Light Company, started this week, and consists of a 150-light machine, with 40 lights in each of the three show windows, which is a greater number of lights than in any other show windows in the city, and the effect is very beautiful. These windows, it is said, contain the largest plate-glass in the world.

United States Plant on a Tug Boat.—The tug No. 1 of the Norfolk & Western Railroad Company is about ready to start. This boat is equipped with an electric light plant installed by the United States Electric Lighting Company. The entire boat is lighted by incandescent lights. There are also two arc lights, run from the incandescent dynamo, to each of which are attached 1,000 feet of cable, enabling the wreckers to take the arc lamps 1,000 feet from the boat, in any direction. There is also on the boat a 6,000 c. p. search light, and the entire plant is under the control of the pilot and engineer.

Electric Lights on the Algonquin.—The Philadelphia branch of the Westinghouse Electric and Manufacturing Company during the past week finished fitting the Clyde Line Steamer "Algonquin," the twin boat of the "Iroquois," built at Cramps' ship yards. Both boats are equipped with some 250 16 c. p. incandescent lights, furnished by a United States dynamo. The trip was made from Cramps' ship yards, Philadelphia, to New York by a large party of gentlemen, and it was remarked by one of the Messrs. Cramps that the "Iroquois" and "Algonquin" are the only vessels that have left their yards with the electric light plant complete and running. W. F. H.

WESTERN NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
465 THE ROOKERY, CHICAGO Oct. 4, 1890.

The Hazeltine Electric Company, St. Louis, Mo., has been incorporated with a capital stock of $650,000. Incorporators, C. N. Hazeltine, Geo. W. Parker, D. R. Russell and others.

Mr. F. E. Calkins, the Chicago manager of the Rockford Electric Manufacturing Company, has moved into The Rookery, in order to be more accessible to the buyers of motors, etc.

The Chicago Electric Battery and Power Company has been incorporated in Chicago, to deal in electrical batteries. The capital stock is $300,000, and the incorporators G. A. Rollins, D. F. Foley and C. E. Gregory.

Another Electric Railway in Chicago.—William Boldenweck, P. J. Maginnis and George Sill have incorporated an electric road under the title of the Northwestern Electric Street Railway, with capital stock of $200,000. They expect to construct their road so as to tap the district lying east of Milwaukee avenue in the extreme northwest corner of the city.

A Proposed Mining Plant.—A Denver (Colo.) dispatch says that articles of incorporation of the Fall Creek Electric Company have been filed with the Secretary of State. The company is to operate in the town of Red Cliff chiefly. The capital stock is $10,000, with George E. Moffet, G. F. Brock, W. B. Montgomery, of Eagle County, Colo., and William Bowen, of Kansas, as stockholders.

Telephone Quotations.—Col. S. G. Lynch, broker, 153 Monroe street, Chicago, furnishes quotations on telephone stocks as follows:

Chicago	$298@$300	Cumberland	$ 59@ $60
Central Union	61@ 62	Wisconsin	117@ 118
Michigan	97@ 99	Bell of Missouri	155@ 160
Great Southern	32@ 35	Iowa Union	20@ 21
Colorado	38@ 40	Missouri and Kansas	55@ 57
Rocky Mountain Bell	40@ 45		

ELECTRIC LIGHT STOCKS.

Chicago Arc Light and Power	$104@$105	Chicago Edison Co	$130@$132

Consolidation.—The Eau Claire, Wis., Brush Electric Company, the Citizens' Electric Company, the Eau Claire Electric Light Company and the Eau Claire Street Railway Company have been bought up by an Eastern syndicate, which will run the whole business under one management and make extensive as well as expensive improvements. The Eau Claire Brush Company and the Citizens' Company have 120 Brush arcs, 1,000 "National" and 850 Fort Wayne alternating incandescents. The Eau Claire Electric Light Company has 60 Excelsior arcs and two 650-light Westinghouse alternators. The Street Railway Company has one 50,000 watt generator and ten 15 h. p. motors, two on a car, and 2½ miles of single track.

Helena, Mont.—The Citizens' Committee of Helena are supporting a plan having for its object the utilization of the water power now going to waste in the Missouri River. The project is to erect a dam across the Missouri River at a point some 13 miles distant from the city, where the quantity and fall of water is estimated to be sufficient to furnish 50,000 horse power, even during the month when the river is at its lowest stage. This power would then be utilized in driving electric generators that would furnish the current necessary to drive motors used in the various industries, for lighting the streets, residences and stores, and for operating the street railways. Two other advantages will accrue from the successful carrying out of the plan. First, an abundance of pure water sufficient to supply the needs of the community for many years to come would be secured, and it would increase the value many fold of the adjacent land in the fine valley through which the river passes and materially aid in converting it into a rich garden section. The members of the Citizens' Committee are Oscar Bradford, A. J. Seligman, Wm. Chessman, C. W. Cannon and L. G. Phelps.

W. DE L.

SOUTHERN NOTES.

NORFOLK, Va., Oct. 4, 1890.

Gatesville, Tex.—Benjamin Worley is getting estimates on a small electric light plant he contemplates establishing.

Darien, Ga.—A movement is on foot to organize an electric light company to furnish street illumination and to supply private parties.

Weldon, N. C.—Steps are being taken looking to the organization of an electric light company. Capt. Thos. Emory can give information.

Valdosta, Ga.—The new electric light plant is completed and the lights were turned on for the first time a few nights ago. There are 200 incandescent lamps.

Athens, Ga.—The city council has granted a franchise to John T. Voss to construct and operate an electric street railway, and the work of construction will begin.

Augusta, Ga.—For some time past the building force of the Electric Railway Company has been engaged in tearing up the old tracks on Broad street of the Augusta and Summerville street railway.

Titusville, Fla.—The Titusville Electric Light Company, recently organized, wants to purchase a 100 incandescent light dynamo and the requisite wire, lamps and fixtures for that number of lights, also engine to furnish power.

Montgomery, Ala.—The city council has authorized the Ball Electric Light and Power Company to erect separate poles for the construction of its electric light system in such places as the board of electrical control may deem advisable.

Luray, Va.—The famous caverns are to be lighted by incandescent electric lights, and the company that owns the property is now negotiating with the representative of an electric light company for the purchase of the requisite equipment.

Clayton, Ga.—A telephone line will be constructed from Tallulah Falls, via Clayton to Franklin, N. C. The contract is in the hands of R. L. Porter, and the line is being put up for Dr. H. S. Lucas, proprietor of the corundum mines near Tallulah Falls, Ga.

La Grange, Ga.—The contract for the contemplated electric light plant cannot be awarded until the assembling of the Georgia Legislature in November, at which time permission will be obtained to issue bonds for the purpose of establishing the plant. E. D. Pitman, mayor, can give full particulars.

Lynchburg, Va.—The West Lynchburg Land Company has received a letter from C. H. Harman, president of the National Improvement Company, of New York, stating that all arrangements and contracts have been made for the establishment of an electric street railway that will almost encircle the city.

Chattanooga, Tenn.—Mr. Jesse Dugger, the city electrician, acting under instructions from the council committee on lights, has been for sometime busy capping gas lamps situated at those points where it is intended to place electric lights. Under the new contract recently made the city can have 42 more arc lights erected without incurring any additional expense. Y. N. B.

ENGLISH NOTES.

(From our own Correspondent.)

LONDON, Sept. 24, 1890.

A Mho-Hour Meter.—Among the instruments sent in, in connection with the Paris Municipal Electric Meter competition, is one devised by M. Hager, which has been christened a "mho-hour meter" by M. Hospitalier. This name is somewhat cacophanous, and it is difficult to see without further explanation than has yet come to hand why the instrument should be so called. The power expended per second through a resistance R and absorbing E volts is, as we all know $\frac{E^2}{R}$, and if E is constant (as it presumably is in a constant potential circuit) the energy expended per second varies as $\frac{1}{R}$, and it is this quantity which M. Hager's instrument measures. But as the current passing through the instrument is also proportional to the conductivity, provided the difference of potential is constant, I should have thought the more usual name of "coulomb meter" would have served the purpose just as well.

Fire Office Rules.—The discussion on this subject in the columns of the *Times*, which was opened some six weeks ago by Maj. Flood Page, still continues, and it seems probable that an earnest effort will be made in the coming autumn to draw up a brief set of rules, which shall be equally satisfactory to the fire offices, supply companies and electric light contractors. I doubt if this consummation, which is certainly devoutly to be wished, is likely to come about by any action taken by the Council of the Institution of Electrical Engineers. The question has nothing whatever to do with theoretical considerations, and should be settled solely by consultation across a table between representatives of the three parties concerned. The new rules, it is to be hoped, will be considerably more concise, precise and to the point than the well-known fire office rules drawn up Mr. Musgrave Heaphy, against which it has always been urged that, in spite of their voluminous nature, they leave far too much to the discretion of the individual inspector, and in many cases insist upon adding additional expense without any corresponding addition in safety.

The Ferranti Mains.—The Ferranti mains, which have now been the best part of two years in coming to London, have, it seems, at last arrived there. Four sets of concentric mains between Deptford and London Bridge are now completed, and it only remains to connect London Bridge with the various transformer sub-stations for the Deptford dynamos to take the whole of the work. It is to be hoped that more rapid progress will be made with the connecting link than has been made with the Deptford-London Bridge portion, since the London Electric Supply Corporation is under legal edict to stop running the Grosvenor Gallery machines some time this autumn. The mains have frequently been tested under pressures of ten and twenty thousand volts, and have so far withstood the tests. Considering the nature of the Ferranti mains it is not surprising to hear that considerable trouble has been experienced with electro-static effects, owing to which the pressure on the secondaries of what would be the consumers' transformers instead of being 100 volts has been known to attain a value of 130 to 160 volts. As I have told you before, the Deptford station has for some time past been assisting the Grosvenor Gallery station in its duty by means of temporary cables. At the end of last month the

Deptford station took the whole load of the Grosvenor Gallery (some 38,000 lights) for 36 hours without any hitch.

The Electric Transmission of Power for Railway Tunneling Purposes.—An interesting application of electricity for the purpose of transmitting power is now in progress in connection with the Santa Rosa-Mendoza section of the railway line connecting Buenos Ayres with Valparaiso. This section of the line crosses the Andes by a series of tunnels, the highest of which is at an altitude of 10,466 feet above the level of the sea. As the greater portion of the tunneling will be through excessively hard rock, Messrs. J. E. & M. Clarke & Co., the contractors, found it necessary to employ drilling machinery to expedite the work. The cost of fuel would have been prohibitory, and as there was not sufficient water power close to the entrances of the tunnels, it has been decided to utilize the water in the valley below. Two power stations have been erected, one on the Chilian and one on the Argentine side of the mountains. At the former a head of 600 feet and at the latter of 400 feet is available. On the Chilian side twelve 80 h. p. Girard turbines are used, each driving direct on to a 54-kilowatt dynamo. The station on the Argentine side is somewhat smaller. The current is conveyed in each case about two miles, at a pressure of 400 volts, to two motors, which drive air compressors, which in turn work the drilling machines. As this is probably the first instance in which electricity has been used for tunneling purposes on so large a scale, it will be interesting to watch the results.

News of the Week.

THE TELEGRAPH.

A union telegraph company has been organized among the farmers of Cass County, Mich., for private convenience.

Meeting of Telegraphers.—The annual meeting of the telegraphers' mutual benefit association will be held in New York on Wednesday, Nov. 19, 1890. The secretary, Mr. Thomas E. Fleming, is sending out blank proxies for the signatures of members who cannot attend the annual meeting.

Dividend and Quarterly Report.—The Mexican Telegraph Company has declared a quarterly dividend of 2½ per cent., payable Oct. 13, to stock of record of Oct. 4. The gross receipts of the company for the quarter ending Sept. 30 (partly estimated) were $9,618; expenses, $16,500; net, $74.118; dividend, $17,815; surplus, $26,303; total surplus, $118,375. The total receipts for the nine months of the current year have been $299,576, as against $266,473 for the corresponding period last year.

THE TELEPHONE.

Change of Address.—The office of the secretary of the National Telephone Exchange Association has been moved from 510 West 23d street to 20 Cortlandt street, this city.

Col. Anthony D. Bullock, President of the City and Suburban Telegraph Association, and of the Bell Telephone Exchange, a prominent and wealthy capitalist, and a highly esteemed citizen, died of apoplexy in Cincinnati Friday evening of last week.

Bell Telephone Suit.—In the United States Circuit Court at Boston, Mass., last week, the government asked for an extension of time in which to take testimony in the case of the United States against the Bell Telephone Company. The defendant's counsel filed a formal protest, but made no argument, and the court extended the time to Jan. 1, 1891. Subsequently a request of the government for an order authorizing the employment of a stenographer to assist the examiner was refused.

New Officers Elected.—The Northwestern Telephone Exchange Company recently elected the following officers at Minneapolis, Minn.: President, Levi Sprague; secretary and treasurer, Charles J. Glidden; directors, Levi Sprague, Charles J. Glidden, A. S. Adams, C. E. Adams, W. A. Gove, J. E. Hudson, Francis Jewett, J. W. C. Pickering, A. C. Russell, Thomas Sherwin, James A. Weston and H. A. Whiting. This is one of the Erie Telephone Company's sub-companies.

THE ELECTRIC LIGHT.

Delphos, O.—The Electric Light and Power Company has increased its capital stock from $25,000 to $40,000.

Stanberry, Mo.—The Stanberry Light and Power Company has been formed; capital, $7,000; incorporators, F. A. Weimer, J. S. Lindley and D. F. Hill.

Thurlow, Pa.—The United States Electric Lighting Company, through its Philadelphia office, is installing a 30-light arc plant for the Standard Steel Castings Company.

New Alternating Arc Plant.—The new erecting shops of the Baldwin Locomotive Works are being equipped with a 40-light alternating current arc Westinghouse dynamo.

Reed City, Mich.—The City Council of Reed City has granted a franchise to George L. Beatle and James H. Andrews for an electric light plant, to continue in force for the next 20 years.

Doylestown, Pa.—The Doylestown Gas Company has bought through L. E. Meyers, the Philadelphia agent of the Edison Company, 100 arc lamps and 750 incandescents to be put up at once.

Altoona, Pa.—The Juniata shops of the Pennsylvania Railroad Company are being fitted with a 40-light alternating arc plant and 600 incandescents, furnished by two 400-light United States dynamos.

Electric Lights in a Royal Palace.—The Emperor of Austria has decided that the electric light shall be introduced into his palace in Vienna. Eight thousand incandescent lights will be required.

Increased Economy.—It is estimated that economies inaugurated by the Westinghouse Electric and Manufacturing Company will save above $200,000 per annum without impairing the service.

Wires across the Rio Grande River.—The President has approved the act authorizing the Texas Mexican Electric Light and Power Company to erect wires across the Rio Grande River at Eagle Pass, Tex.

Kalamazoo, Mich.—The Kalamazoo Electric Company is now under the management of Mr. James Campbell, with his brother, S. L. Campbell, late of Muskegon, as superintendent. After Jan. 1 next the latter gentleman will assume the management.

Derry, Pa.—A charter has just been granted at Harrisburg, Pa., to the Derry Electric Light Company, with a capital of $5,000. The directors of the new corporation are: Geo. F. Huff, of Greensburg; A. O. Coven, of Derry, and Edward Pitcairn, of Wilkinsburg, Pa.

Edison Contracts in the Central States.—During the week ending Sept. 27, Mr. S. D. Nesmith, agent for the Edison General Electric Company for the Central States district, with headquarters at Cleveland, O., closed contracts for one 35 arc light plant for Salineville, O., and for an increase of 500 lights for the Wooster (O.) Electric Light Company.

Electricity Replaces Natural Gas.—The National Tube Works Company has until recently used natural gas for lighting in and about its immense works at McKeesport, Pa. The company a short time ago decided that the gas had become too scarce an article to be used for illuminating purposes, and accordingly substituted for it an arc light plant of 30 lights capacity.

Municipal Electric Lighting Fallacy.—Mr. Victor Rosewater, of Johns Hopkins University, in a contribution to the New *York Independent* stated that the total cost of the street arc lamps at Ypsilanti, Mich., was but $23 per year. Mr. W. R. Coats, who was the engineer in charge of the construction of the Ypsilanti water-works, with which the electric lighting plant is connected, writes to the editor of *Engineering News* that, figuring the interest on the cost of the plant at 5 per cent. and the depreciation at 10 per cent. (which, however, he considers very low), the cost of the Ypsilanti lights is $86 per lamp per year.

Recent Westinghouse Installations.—Among the new central station plants of alternating current lighting, the Westinghouse Company has obtained contracts from Owensboro, Ind., 750 lights; Akron, O., 1,500; Bedford, Ind., 750 lights; Norwalk, O., 1,000; Lykens, Pa., 750; Penn Yan, N. Y., 750. In addition to these a number of the older central station plants have increased their capacity considerably. Among those having contracted with the company for an increase during the month of September are: Englewood, a suburb of Chicago, Ill., for 3,000 lights; Bay City, Mich., 3,000 lights; Duluth, Minn., 750 lights, and Youngstown, O., 750 lights. The plant in Youngstown is not yet in operation at all. After the company had been organized the management contracted with the Westinghouse Electric Company for alternating current apparatus of a capacity of 2,250 lights, but even before this machinery had been installed the management realized that the demand was greater than it had been at first anticipated and therefore the increase was ordered.

APPLICATIONS OF POWER.

Marquette and Ishpeming, Mich., are to be connected by an electric road.

New Electric Line.—Work has begun on the Braddock (Pa.) & Turtle Creek Electric Railroad, and the managers of the enterprise are promising the citizens that cars will be running on the road ere snow flies.

Greensburg, Pa.—The electric railway company is just about ready to begin operations. The work on the line is completed. The Westinghouse system will be used, and for a time the road will be in charge of Westinghouse experts.

Merrimac Valley Electric Road.—The petition of the Merrimac Valley (Mass.) Horse Railroad Company for right to extend its tracks to Andover, and to use electricity as a motive power over all its lines was granted, and a year given the company in which to complete the extension.

Uniontown and Fairchance, Pa., six miles apart, are to be connected by means of electrical rapid transit. Uniontown is the capital of Fayette county. Recently several manufactories have been established in the town, and with the new activity comes a demand for modern methods of street travel.

Charter Granted.—On the 25th of September a charter was granted at Harrisburg to the Verner Street Railway Company, of Allegheny City, Pa., with a capital of $6,000. The directors are: A. M. Neeper, A. C. McCallum and W. I. Mustin, of Pittsburgh; J. W. Dalzell, G. W. Henderson and J. N. Hill, of Allegheny, Pa.

Electric Power for Drilling Oil Wells.—A Pittsburgh inventor named Webber recently got it into his head that electricity could be used in the drilling of oil wells with the same facility with which it is applied in many other kinds of work. Last week he was granted a patent upon a device which he has worked out. It consists of a series of motors in tandem, connected in such a way as to practically make one motor. The design is to get the power within a 6-inch diameter, so that the entire mechanism, which much resembles a common boiler, can be lowered in the well and the power applied at the bottom. Projecting from the mechanism is a rod which resembles a piston rod working in and out of the cylinder; upon this rod the drill bits are firmly fastened and the apparatus is then lowered in the well.

MISCELLANEOUS NOTES.

Annual Meeting.—The annual meeting of the Edison Doll Company will be held in Portland, Me., Oct. 16.

Electrical Men in Another Business.—F. J. Sprague, E. H. Johnson, J. W. Wingate and others have organized a stock company to erect an ice factory at Winston, N. C.

Care Required of an Employer.—It has been decided by the Supreme Court of the United States that neither individuals nor corporations are bound, as employers, to insure the absolute safety of the machinery or mechanical appliances which they provide for the use of their employés, but they are responsible for any injury which may happen through a defect of the machinery which was or ought to have been known to them and was unknown to the employé.

A very neat exhibit has been sent to the Spokane Falls Electrical Society, by the Consolidated Fruit Jar Company, of New Brunswick, N. J., to be used at its convention this month. The whole is in the form of a large picture frame, with oak molding around the outside and the background covered with plush, the size of the entire frame being three feet long by three feet wide. On the plush, in the centre of the frame, there is an old plank about 18 inches wide and three feet long chopped and hacked in an irregular shape. The board was then covered with shellac and powdered with silver. In raised letters from the powdered silver appears the name of the company, "The Consolidated Fruit Jar Company," with the place of its New York office, "49 Warren street," and also the location of the factories, "New Brunswick, N. J." On either upper corner of the powdered silver plank appear the words, "Metal Novelties" raised in colored work from the surface of the plank. Along the lower part of the board in raised light-blue letters appear the words "Electrical Novelties," with small streaks of "lightning" running hither and thither over each letter of the above words. To the left of the silvered board there is an excellent representation of a cobweb made from the company's 2.9 ampère fuse wire. In a long line extending from the left of the board to the right, beginning at the left-hand corner and running in a regular line around the silvered board over the top of same, then in jagged course down to the right-hand corner of the plush frame, is a row of lacquered metal spools wound with fuse wire, which gradually increase from the first spool, with wire of a capacity of 2.9 ampères, all the way up to 5, 10, 15, 20, 25, 30, 40, 45, 50, 75 and 100 ampères at the last spool. There are some 15 or 20 sizes of fuse wire upon the board wired into novel designs. In large letters in hammered fuse wire in the upper left-hand and right-hand corners appear the words "Fuse Wire;" and on the red plush background, between the powdered silver board and the oaken frame, are two coils of rope made from fuse wire, and holding them down is a strip of 200 ampère fuse wire ribbon.

Quotations on Electrical Stocks.—Mr. F. Z. Maguire, electrical securities, of 18 Wall street, this city, reports the following quotations of Saturday, Oct. 4, from New York, Boston, Washington and Pittsburgh:

NEW YORK.

	Bid.		Bid.
W. U. Tel. Co.	81⅛	Edison Gen. Elec. Co.	94
American Tele. & Cable	83	Edison Gen. Co. Def'd	55
Cent'l & So. Amer.	155	*Consol'd Elec. Lt. Co.	59
Mexican	205	*Edison Illn'g Co., N. Y.	70
Com. Cable Co.	.....	U. S. Elec. Lt. Co.	30
Postal Tel. Cable	39	North Am. Phon'gph.	....

BOSTON.

	Bid.		Bid.
Thomson-Houston	50⅜	Ft. Wayne Co.	11¼
" Pref'd	26	Am. Bell	220
" Series C.	11⅛	Erie	48
" " D.	6	New England	51½
" Int. Co.	....	Mexican	.80
Thomson Welding Co.	200	Trop. American	.....
Thomson Eu. Welding	77	Edison Phon'gph Doll	1½

WASHINGTON.

	Bid.		Bid.
Penna. Telephone	25	Eck. & Sold. Home Elec.	
Ches. & Pot. Telephone	72	Ry.	62
Amer. Graphophone	14⅞	*Georget'wn & Tenallyt'n	53½
U S. Electric Lt. (Wash.)	155		

PITTSBURGH.

	Bid.
Westinghouse Electric Manufacturing Company	34

*Ex. dividend.

PERSONAL

Mr. James Dredge, editor and proprietor of London *Engineering*, who is now in the United States attending the meetings of the British Iron and Steel Institute, visited the works of the Westinghouse Electric and Manufacturing Company, at Pittsburgh, last week, and also the central stations of the various local lighting companies of the city. Mr. Dredge is engaged in the preparation of an article on electric and cable roads in the United States, for publication in his paper.

Industrial and Trade Notes.

Mason Regulators.—The boilers in the new factory "K" of the Thomson-Houston Electric Company at Lynn, Mass., have all been fitted with the Mason damper regulators.

The Fitchburg Engine Company, through Mr. W. E. Sheldon, reports continued prosperity, and large and increasing sales of its well-known machines. Several contracts of considerable size have been closed recently, and many prominent installations are now under way.

James Schawel & Company, 29 John street, this city, are making a specialty of platinum wire for incandescent lamps. This wire is of the finest grades and is made as small as one thousandth of an inch in diameter, and specially hard drawn through ruby plates to give a smooth and uniform surface.

Eureka Tempered Copper.—Mr. Wm. T. Ramsey, assistant superintendent of the Federal Street and Pleasant Valley Passenger Railway Company, of Allegheny, Pa., says that after a year's experience with Eureka Tempered Copper he can heartily endorse it and recommend it for all descriptions of bearings and for electrical purposes, such as commutator bars, trolley wheels, etc., etc.

A Big Belt Ordered.—Chas. A. Schieren & Co. received about six months ago from the Louisiana Electric Light Company, of New Orleans, La., an order for a double leather belt 160 feet long and 72 inches wide, and one 550 feet long and 48 inches wide. A duplicate of the 72 inch belt has just been ordered by the same company. These belts are probably the largest and heaviest in the world.

Gould & Eberhardt, of Newark, N. J., report a good demand for the Eberhardt's patent shapers, drill and tapping machines, and entirely automatic gear cutters, and have recently booked orders for the latter machines to the Westinghouse Electric and Manufacturing Company, Prentiss Bros. and F. E Reed, and a carload is ready for the McGill University, in Canada, besides a number of foreign shipments.

Mr. Chas. G. Armstrong, of the Great Western Electric Supply Company, has been working on a new fire-alarm box which is said to offer many advantages over the release key or release man system now in use. It will be ready in about a month, and will probably find favor with small as well as large communities. The above firm is also finding a large call for the Chubbuck brackets and break-arms, which were recently described and illustrated in our columns.

Of the numerous forms of lamp guards now in use, many need a shade-holder, and others have so coarse a mesh as to afford but little protection. Observing this, Mr. Geo. Cutter has brought out a new form of expanding wire guard which is intended to combine the good features of all the others. It has five rings surrounding the part of the bulb which most needs the protection, has sliding sleeves which adapt it to any 16 c. p. lamp, and has a neat appearance. The Great Western Electric Supply Company are placing this guard upon the market.

The Massachusetts Electrical Engineering Company, in addition to its offices at 4 Post Office square Boston, has leased additional rooms on Fort Hill square for the manufacture of tested fuse wire, the demand for which has reached such proportions that it is almost impossible to supply the trade. This fuse wire is of uniform quality and ampère test, and is put up in one pound rolls, a certificate enclosed, and then sealed. Attached to each roll is a tag giving its advisable ampère carrying capacity and

fusing point in open air. Special tested wire is furnished on application.

An Economical Boiler.—The Lynn Belt Line Street Rail way Company, of Lynn, Mass., is attracting considerable attention on account of its economic operations. Charging all coal used in a day's run of 18 hours gives a cost of only 1.18 cents per car per mile. This record has probably not been equaled anywhere, and is said to have been made possible by the use of the new improved Root water-tube steam boiler, manufactured solely by Messrs. Abendroth & Root Manufacturing Company, 28 Cliff street, New York City. A number of these boilers have been adopted by well-known cable and electric street railway companies, who find them very desirable for street railway plants.

C. H. Vincent & Co., 15 Cortlandt street, this city, have installed a five h. p. vertical engine of the latest type in Liebman's brewery, Brooklyn, N. Y., to run 21 hours a day with a load of between 40 and 50 incandescent lamps. The same company has installed a 35-h. p. Ball engine in the same place. They have lately brought out a new line of vertical engines ranging from 5 to 20 h. p., and have found a great demand for them, as the Ball engines which they handle are not made in these small sizes. As these engines have specially sensitive automatic governors they are well adapted to electric light work.

Graphite Bushings on the Electric Headlight.—Mr. George C. Pyle, the inventor of the electric head light, commenced to use graphite bushings in connection with the same as early as the fall of 1884, and has continued to use them up to the present time. It has taken a long time to develop and perfect the headlight, but the same is now fully perfected and described by Mr. M. B. Leonard in his paper on "Electric Lighting in the Railway Service," and published in THE ELECTRICAL WORLD of July 12, 1890. The Graphite Lubricating Company, of Jersey City, N. J., is furnishing the graphite bushings for the small steam engine and dynamo as described by Mr. Leonard, and has very recently furnished to the Steel Pulley and Machine Company, of Indianapolis, Ind., which is manufacturing the steam engines and dynamos for the National Electric Locomotive Headlight Company, a sufficient quantity of graphite bushings to equip 164 locomotive engines with electric headlights. These lights are in use on the following railroads: Vandalia, Wabash, Cincinnati, Hamilton & Dayton, Michigan Central and Indianapolis, Decatur & Western, where they have been in constant operation for about two years.

Prosperous Outlook for the Westinghouse Company.—Experience in the electrical business has always shown that during the summer months the industry is less active than during the remainder of the year. It is in the summer that the largest electric companies get an opportunity to catch up with filling those orders with which they are behind; or else they have a chance for working ahead and getting ready for the time when the heavy fall trade begins. Reports from all over the country show that this year is the greatest the electrical industry has ever known, and one of the largest companies, the Westinghouse Electric and Manufacturing Company, is already so stocked with contracts for the equipment of electric lighting central station plants, for isolated plants, for electric railway equipment, etc., that the works are now being operated at their utmost capacity day and night, with every prospect of having to continue in that way for the entire winter. Since the company entered the field of constructing electric railway motors, especially, it has been obliged to increase its facilities very extensively. The many advantages of the company's railway motor have made it already familiar to most of the electric railway people in the country, and have brought to the Westinghouse Company a very large number of contracts. The orders for alternating current incandescent lighting apparatus received during the month of September aggregate 28,250 lights, which is over a thousand lights for each working day. Besides this, the demand for Westinghouse alternating current arc lighting apparatus has been unusually heavy and the company is far behind with its orders in that department. In the electric railway department, it is the same. The company has orders for the equipment of 40 roads, calling for machinery valued at almost $1,000,000, and still the demand is increasing. The noiseless motor of the company on the Pleasant Valley electric line in Pittsburgh continues to attract attention.

Chadbourne, Hazelton & Co., selling agents for the Wenstrom Consolidated Dynamo and Motor Company for the United States, report the following sales of incandescent dynamos and motors for the last six weeks: Shortlidge's Academy, Media, Pa. one 80 ampère dynamo; Southwestern Printing House, 1,240 S. Seventh street, Philadelphia, one 30 ampère dynamo; United Electric Equipment Company, 706 Walnut street, Philadelphia, one 30 ampère dynamo and one 5 h. p. motor; Hobart Electric Company, one 50 ampère dynamo; Southern Electric Manufacturing and Supply Company, 111 Baronne street, New Orleans, La., one 5 h. p. motor; Wm. Sellers & Co., Sixteenth and Hamilton streets, Philadelphia, two 5 h. p. motors, one 30 h. p. motor, one 35 h. p. motor, one 40 h. p. motor and one 15 h. p. motor; A. Kern & Sons, Eagle Flour Mills, Milwaukee, Wis., one 400 ampère dynamo; Gaynor Electric Company, 439 West Main street, Louisville, Ky., one 50 ampère dynamo, two 225 ampère dynamos; Wilmington City Railway Company, Wilmington, Del., one 180 ampère dynamo; J. H. Hunter & Bro., Reading, Pa., one 5 h. p. motor; Genesee Hotel, Buffalo, N. Y., two 125 ampère dynamos; Borsch & Rommel, 1,324 Walnut street, Philadelphia, one 2 h. p. motor; R. H. Foederer, Frankford Junction, Philadelphia, one 125 ampère dynamo; Ryland-Robinson Company, San Francisco, Cal., one 50 ampère dynamo; Star Electrix Company, 1,320 Wallace street, Philadelphia, one 50 ampère dynamo; United Electric Equipment Company, 706 Walnut street, Philadelphia, one 50 ampère dynamo; Electric Manufacturing Company, Greenbush, N. Y., one 30 ampère dynamo; Harrisburg Electric Company, Harrisburg, Pa., one ½ h. p. motor; Barret Elevator Company, Cleveland, O., one 16 ampère dynamo; Louisville Steam and Electric Motor Power Company, Louisville, Ky., two 80,000 watt dynamos; Schuylkill Electric Railway Company, Pottsville, Pa., two 50,000 watt generators; Geo. Miller & Son, Philadelphia, one 180 ampère dynamo; Darby & Sons, Philadelphia, one 50 ampère dynamo; Louisville Leather Company, Louisville, Ky., one 30 ampère dynamo and one 2 h. p. motor; Commercial Club, Louisville, Ky., two 450 light dynamos.

Mr. J. W. Parker, the manager of the Philadelphia office of the "C. & C." Electric Motor Company, and also of the Philadelphia office of the Ball Engine Company, reports the following sales since the opening of his office in May last: To the South Side Land and Improvement Company, of Richmond, Va., one 100 h. p. Ball engine and one 125 h. p. boiler, building the plant complete to operate a Sprague electric railway from Richmond to Manchester; the Columbia Electric Light Company, of Philadelphia, two 100 h. p. compound Ball engines, to operate an incandescent plant furnished by the Ft. Wayne Electric Company with two 1,000-light machines, to be in operation about Oct. 1, 1890; the Harlan-Hollingsworth Company, of Wilmington, Del., one 175 h. p. and one 100 h. p. standard Ball engine, to operate a Thomson-Houston direct current incandescent plant to light the shops and yards; J. B. Van Sciver & Co., Camden, N. J., one 50 h. p. Ball standard engine and one 60 h. p. boiler, building the plant complete, to operate a "standard" direct current incandescent plant in the new addition to their stores; the Schuylkill Electric Railway Company, of Pottsville, Pa., one 175 h. p. standard Ball engine that will operate a Wenstrom electric railway, the first Wenstrom road to be opened. He has also sold the following "C. & C." electric motors in Wilmington, Del.: W. W. Bullock, saw and planing mill, a 15 h. p., 220 volt motor; the J. T. Clymer Carriage Works, a 15 h. p., 220 volt motor; I. T. Quigley Morocco Works, a 15 h. p. motor, 220 volts; J. G. Baker Morocco Works a 15 h. p. motor, 220 volts; Wilmington Printing House, a 4 h. p. motor; Mercantile Printing House, an 8 h. p. motor; Fell and Josephs, coal elevating, a 5 h. p. motor; H. A. Miller, plumber, an 8 h. p. motor, and a great number of smaller machines, especially for the little "C. & C." fan outfits and others for driving ceiling fans. In Philadelphia he has sold to Mun & Shiver Printing House a 3 h. p. motor; C. S. Clunn & Co., an 8 h. p. motor; Hansom Bros., a 10 h. p. motor; Spencer Vanfleet & Co., printers, a 3 h. p. motor, and about $10,000 worth of small ⅛, ¼, ½ and 1 h. p. motors, and the "C. & C." fan outfits. Inquiries are numerous and Mr. Parker is anticipating a very large business in engines this fall. The motor business is very encouraging. The "C. & C." motor has successfully displaced in several places in Philadelphia and Wilmington the gas engine, in every case making a record of energy consumed very materially less than what was paid for in the case of gas engines. Mr. Parker is enlarging his business, and adding new electrical novelties and combinations, and expects to open the new year with a very compelte line of supplies.

Answers to Correspondents.

Questions to be answered in this column must be of general electrical interest, and must be accompanied by real name and address as a guarantee of good faith. No notice will be taken of questions regarding apparatus unless enough details are given to permit a definite answer, and no dynamo or motor designing will be done.

Patents on Shunt Winding.—Can you tell me whether there are any patents on shunt winding in dynamos? Would it be possible to infringe on any patent by designing a dynamo along the lines of Hering's book, for example? A. H.

You will run no risk from any general patents in following out the lines of design laid down by Hering. It is barely possible that you might happen to hit upon some special patented features, but we hardly think you need trouble yourself on that score.

Elevator Annunciators.—Can you state on what grounds certain parties claim a monopoly of elevator annunciators, compelling others to pay royalty for using them? B.

The point covered by the patent alluded to is the use of flexible wire connections following the car in its movement. As this forms the most practical way of operating an elevator annunciator, it gives a pretty good hold on the business, unless one cares to use the other plan of stretching a series of direct wires vertically up and down the well and making contact with them by brushes on the latter, a scheme which is somewhat uncertain in its action.

Arc Lamps on Incandescent Circuits.—Can you inform me how arc lamps are run on incandescent dynamos of 110 volts or thereabouts? Do they require any resistance in the circuit? If so what is the easiest way of putting it in? J. M.

Special lamps are made which operate very successfully on incandescent circuits. One well-known variety is handled by the Electrical Construction and Supply Company, 18 Cortlandt street, New York. Where the voltage on the incandescent mains is greater than 45 to 50 volts, which is requisite for one arc lamp, it is usual to run two or more lamps in series, according to the voltage. If you do not care to run two arc lamps, a series incandescent lamp would make an excellent resistance for the purpose. It should be put directly in series with the arc lamp.

Metallic Circuits for Telephones.—Can you give me through the medium of your paper the names and addresses of some American telephone companies who have wholly or partially adopted a metallic circuit system owing to the disturbances caused by electric light or railway systems? We have tried the common return wire grounded in one or several places, and not grounded at all, but only with moderate success so far as railway interference goes and with none or hardly any so far as light interference is concerned. N. W. & B. I. T. Co.

Your experience shows very plainly that the trouble you have is due to induction, and for this there is no remedy so far as we know except the individual metallic circuits. A number of telephone companies have adopted the metallic circuit, and you probably can get some useful information on the question by writing to the managers of the telephone exchanges at Cleveland, O.; Chicago, Ill.; Atlantic City, N. J.; New Haven, Conn., and Richmond, Va. Among these we think you will be able to find the information you desire.

Electric Welding Apparatus.—(1) Can any alternating current dynamo of sufficient power be used for electric welding, or is it necessary to use one constructed specially for the purpose? (2) How much electrical power is required to weld two-inch boiler tubes? (3) What is the loss in the transformer or welder? (4) Is it customary to run several welders from one dynamo? (5) In running several motors of a 110-volt constant potential circuit, where fluctuations of load are considerable, is it usually necessary to use an automatic regulator in the dynamo room to maintain sufficient constant potential? (6) Can a three-wire system be operated without arrangement with the Edison Company? SEEKER.

(1) Yes, if a special transformer is used, and the machine is not overloaded. It is probably better, however, to employ a special dynamo, particularly where heavy work is to be done. (2) We have seen no figures covering this question. (3) Considerable; the exact amount has never been published. The losses occur both in transformer and welder. (4) Yes, although for very large work a single welder to a dynamo is frequently used. (5) Where the fluctuations of load are considerable, it is desirable to use a compound wound machine. We would not advise any other kind of automatic regulation for a constant potential machine. (6) The Edison Company claims the sole right to use the three-wire system.

Business Notices.

Battery Cut-Out, Cheap.—Sensitive, reliable, never requires attention. Gas lighting much improved by its use. Electric Supply Co., of 105 South Warren street, Syracuse, N. Y.

To All to Whom these Presents May Come, Know Ye.—By a resolution duly passed by the corporation known as "Hazazer & Stanley," it was voted to change the name of said corporation, with permission of the court, from "Hazazer & Stanley" to "Stanley & Hall."

Now, by order of the Supreme Court, it is made known that from this time the name of said corporation is and shall be "Stanley & Hall." A. F. STANLEY, President.

Through Vestibuled and Colonist Sleepers Between Chicago and Tacoma, Wash., and Portland, Ore.—The Wisconsin Central and Northern Pacific lines run through Pullman vestibuled and Colonist sleepers between Chicago and Tacoma Wash., and Portland, Oregon. The train known as the "Pacific Express" leaves the Grand Central Passenger Station, at the corner of Fifth avenue and Harrison street, at 10:45 P. M. daily. For tickets, berths in Pullman or Colonist sleepers, etc., apply to Geo. K. Thompson, City Passenger and Ticket Agent, 205 Clark street, or to F. J. Eddy, Depot Ticket Agent, Grand Central Passenger Station, corner Fifth avenue and Harrison street, Chicago, Ill.

Intelligent People who are familiar with the respective advantages which are offered by the several competing railroad lines between Chicago, St. Louis and Kansas City, and who desire to travel with the utmost speed, safety and comfort, always take the popular and reliable Chicago & Alton Railroad between these points, and passengers going to or coming from the South, via St. Louis, or when going to or coming from the West, via Kansas City, should insist upon having tickets that read over the Chicago & Alton. It is the only road with three complete and elegantly equipped trains daily between Chicago and each of the points named, and no railroad managers in America have a more intelligent appreciation of the wants of the traveling public than do those of the famous Chicago & Alton.

OUR ILLUSTRATED RECORD OF ELECTRICAL PATENTS

U. S. PATENTS ISSUED SEPT. 30, 1890.

437,183. Electric Meter; Richard N. Dyer, East Orange, N. J. Application filed Jan. 5, 1888. The meter consists of an electric motor and two escapements controlled by a pendulum. One pendulum bob is a closed coil of wire which swings through the field of an electromagnet in the main line or in a shunt around a resistance in the main line. This pendulum then is accelerated in direct proportion to the flow of current through the coils of the main line magnet. The other pendulum is not accelerated electrically, and the bob of one or both pendulums is adjustable, so that the initial speed can be made the same. Both escapements are driven from one motor and connected with a differential indicator through an epicytic gear.

437,203. Method of Adjusting Watches; George E. Hunter and Fred. H. Corthell, of Elgin, Ill. Application filed Sept. 23, 1889. This patent is for a method of selecting watch balances or hair-springs consisting of vibrating the same a number of times in connection with the registering mechanism and is controlled by a vibrating reed.

437,204. Method of Adjusting Watches; George E. Hunter and Fred. H. Corthell, of Elgin, Ill. Application filed Sept. 23, 1889. Patent on the method of adjusting balances or hair-springs in extremes of temperature by vibrating the balance or hair-spring a predetermined number of times within a compartment having the desired temperature and registering the time of such vibrations.

437,205. Apparatus for Adjusting Watches; George E. Hunter and Fred. H. Corthell, of Elgin, Ill. Application filed Feb. 13, 1890. The object of the invention is to render possible a selection of a balance and hair-spring which when combined will produce the best results. It consists in electromagnetic means for actuating and controlling mechanism for registering the temperature required for a predetermined number of vibrations of a balance with a standard hair-spring or a hair-spring with a standard balance.

437,206. Apparatus for Adjusting Watches; George E. Hunter and Fred H. Corthell, of Elgin, Ill. Application filed Feb. 13, 1890. The invention relates to the adjustment of watches and is designed to facilitate the adjustment of the balance and hair-springs in extremes of temperature. To this end the balance is vibrated a predetermined number of times in connection with a standard hair spring after the manner determined which has its temperature kept uniformly at one of the extremes. The time required for such vibrations is registered by mechanism outside of the compartment but so connected with the vibrating mechanism that when the latter is started or stopped the former is simultaneously set in motion or stopped and shows exactly the time of the vibrations.

437,210. Electric Street Car; Luther H. Leber, Pittsburgh, Pa. Application filed June 21, 1890. The arrangement of this invention consists of a combined rheostat and a brake mechanism intended to apply the brakes and turn off the current at the same time.

437,272. Distribution and Regulation of Electric Currents; Franz Wilking, of Berlin, and Hermann Muller, of Nuremberg, Germany. Application filed March 28, 1890. The invention relates to improvements having for their object to regulate the terminal tensions of all the fibres in a complicated system when there is variable consumption of current, or to allow of unequal loss of tension in the several fibres with a maximum consumption of current. These objects are effected without the wasteful use of resistances, and the general method employed is to use a storage battery with variable switches to attain the end desired.

437,307. Automatic Telegraphy; David Kunhardt, of Aachen, Germany. Application filed March 20, 1890. The apparatus is of an extremely complicated character, consisting in the main of a drum containing three groups of 22 pieces of projective weights which enter into mechanical contact with a corresponding system of springs, and the different letters are sent by the different combinations of these contacts. The apparatus is so arranged that three operators can send to the same receiving apparatus, and the messages, although thoroughly mixed on being received, are systematically arranged so that they can be readily written out.

437,311. Artificial Ground and Compound Metallic Circuit Systems; Charles Edward McCluer, Richmond, Va. Application filed June 1, 1888. This invention is for the purpose of avoiding electrical interference between the several lines on telephone, telegraph, or other multiple line system, or from leakage on light or power lines. This is an extension of the general metallic return plan which has been already successfully tried in various places. It comprises the combination of the multiple lines of a system to be protected with a general return wire of low resistance compared with the resistance of the several lines which are connected with it. The result is considerably to lessen any interference due to leakage.

437,324. Electric Cut-Out; Elmer E. Bailey, Everett, Mass., and George J. Galbraith, Boston, Mass. Application filed May 27, 1890. The invention relates to improvements in cut-outs for automatically breaking the circuit of telephones, telegraph instruments and the like, in case of reception of current from a high potential line. The instrument consists of a combination of an electromagnetic grounding device with the additional protection of a fuse wire. The telephone or telegraph currents will not be sufficient to operate the electromagnet while an entering current of high potential could do so.

437,330. Electric Cable; David Brooks, Jr., Philadelphia. Application filed Dec. 29, 1888. The cable described consists of a bunch of dry fibrous covered wires having the interstices between them filled with dry air, a coating of powder on the wires, and the whole enclosed in an air-tight case.

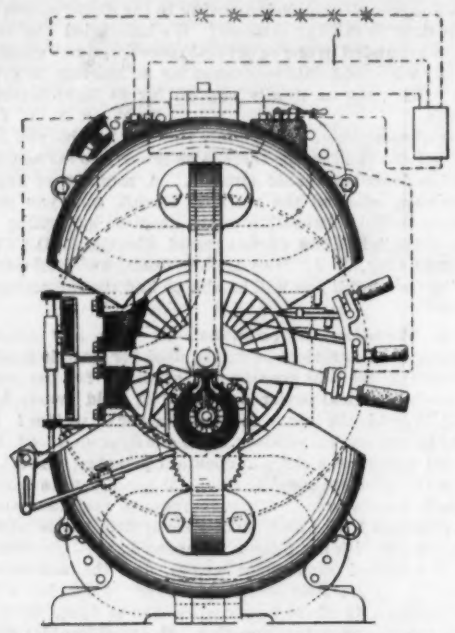
437,348. Apparatus for Operating Signals; Samuel L. Powell, Lewistown, Md. Application filed June 20, 1890. The device is intended to operate signals and semaphores and the like for railway use. It consists essentially of a semaphore lever operated by gravitation and released by a special electric circuit operated by a battery on car at some other convenient point and

including one working rail or car wheel and a contact wheel bearing on a third or electrical rail.

437,352. Electric Hand Switch; Joseph W. Battershall, Attleboro, Mass. Application filed Dec. 24, 1889. The switch described is a four-pole switch for electric lines and the contact is made by insulating ratchet teeth with large bearing surface to secure good contact and provision for a sudden break.

437,358. Electric Railway System; Charles K. Harding, of Atlantic, Ia. Application filed June 9, 1890. The railway system herein described is one of that class which automatically connects a supply conductor in a conduit with sections of a working conductor by electromagnetic means, and is more fully described in the text of the current number of THE ELECTRICAL WORLD.

437,359. Electric Snap Switch; William Hochhausen, Brooklyn, N. Y. Application filed Feb. 17, 1890. This invention relates to the details of the construction of a snap switch by



No. 437,360.—DYNAMO-ELECTRIC MACHINE.

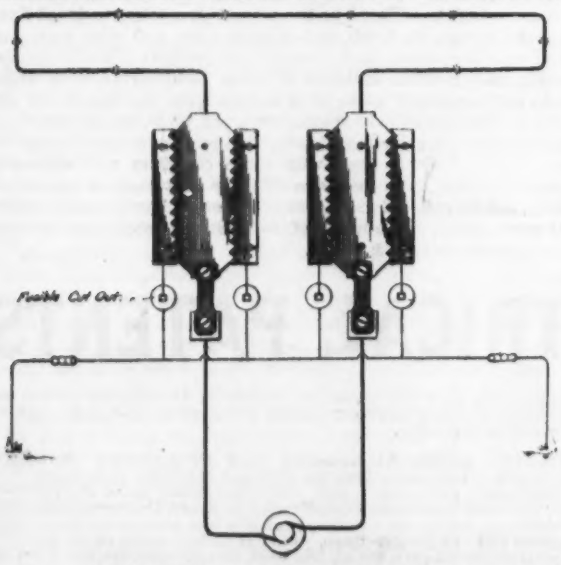
which it is adapted to operate as a current reversing switch or pole changer. A vertical spindle is mounted upon an insulating base, the switch-act uating lever is fastened to the spindle beneath the frame and carrying contact spring plates mounted on the block of insulated material forming a part of or carried by the switch lever contact terminals in the base of the switch and a spiral spring connecting the switch lever to the actuating lever.

437,360. Dynamo-Electric Machine; William Hochhausen, Brooklyn, N. Y. Application filed Feb. 17, 1890. Some of the objects of this invention are to provide for a ready removal of the armature without dismantling the field magnets, to insure the insulation of the armature from a ground, to provide means whereby the armature may be readily centered in a magnetic field in cases where it is subjected to attractive or repulsive influences on its side continuing to give an end thrust on the armature shaft. The invention covers the combination with the connected journal bearings carrying the armature shaft of adjusting mechanism for adjusting and setting the bearings and shafts in different longitudinal positions, and insulating materials to prevent electrical connection between the journal bearings and parts of the field magnet frame upon which the adjusting mechanism bears.

437,362. Electric Cut-Out; W. J. Jenks, Nyack, N. Y. Application filed June 16, 1890. The essential part of this invention is the use of a cut-out magnet for telephone and telegraph systems or the like, situated directly in the main line and nominally carrying the current in use on the line, but operative by a slight increase of current. This arrangement is likely to cut out the line under slight increase of tension.

437,363. Lightning Arrester; Harry M. Halbach, Ashland, Pa. Application filed Jan. 29, 1890. The main feature of the invention is location of the thermal cut-out in the ground circuit. The apparatus consists of a plate with serrated edges and adjustable plates, also with serrated edges, one on either side of it, with a ground wire and fuses therein.

437,369. Electric Alarm; Arnold Tschira, Freiburg, Germany. Application filed July 26, 1890. Patented in Germany, Dec. 10, 1889. This is an improved gauge for automatically indicating when a cask is filled with liquid, and the invention consists in the combination with a suitable float of electric conductors with a circuit which can be closed by the float, an elec-



No. 437,363.—LIGHTNING ARRESTER.

tric bell connected with the conductors and means for holding the float in the cask.

437,387. Magnet Winding Machine; James J. Wood, of Brooklyn, N. Y. Application filed July 29, 1890. This is a machine for facilitating the winding of wire on the spools or bobbins of an electromagnet. The invention covers the combination of a spindle for revolving the magnet, a driving-wheel geared to it, the driving shaft movable longitudinally, a clutch for coupling the shaft or driving-wheel, so that the latter may be driven from the shaft, the clutch lever for connecting the shaft for moving it longitudinally, for connecting or disengaging the clutch, and a spring for normally disengaging the clutch.

437,397. Lightning Arrester for Fire Alarm Boxes; Robert Hudie, of Allegheny, Pa. Application filed June 11, 1890. The object of this invention is to provide for cutting off the electrical connection of the wires leading to the box from the coils operating the mechanism therein, so that the operated mechanism is only brought into connection when it is utilized to give the necessary signal, and at all other times it is out of circuit. Upon a fire alarm switchboard, having a spring key normally in circuit, is placed a spring-operated cross-cut key extending from one pole plate to the other, so that when the cross-cut key is pressed down the line is closed between the pole plates through the cross-cut key, and the operating coils of the alarm box are cut out of circuit.

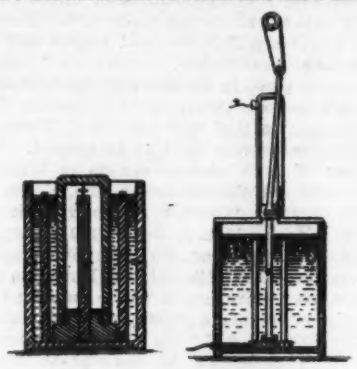
437,393. Galvanic Battery; Edward H. Crosby, Boston, Mass., Assignor to the Crosby Electric Company, of New York, N. Y. Application filed Feb. 8, 1890. The containing jar of this battery is constructed of paper stock or similar material prepared with an outer coating of shellac and an inner acid-proof coating composed of paraffine and ozokerite. The zinc and carbon electrodes in the cell rest on an absorbent pad, and are surrounded by a packing consisting of a dry excitant. This packing is composed of sawdust or wood fibre mixed with an excitant in a dry or crystalline form.

437,412. Rheostat or Rheotome; Marcel Deprex. Application filed Feb. 24, 1888. The rheostat described is formed with a liquid resistance, and the vessel is provided with an inlet and an outlet, so that there can be a sudden flow and renewal of the liquid.

437,422. Telegraphy; Thomas A. Edison, Menlo Park, N. J. Application filed Oct. 23, 1885. This invention covers the combination with the main and artificial lines of an inductive equalizer composed of magnet coils in said lines and an armature core adjustable in relation to the magnet coils and varying their relative inductive action upon said lines.

437,445. Conduit for Underground Wires; Thomas M. Morton, Baltimore, Md. Application filed June 24, 1890. This invention consists in tapered sections of pipe of peculiar construction. The conduit is constructed of tapered tubular sections, each longitudinally divided into an upper and lower half and provided at the small end with an exterior ring-swell and at the large end with a counterbore having an interior ring groove to receive the exterior swell and an exterior collar. The sections have interior channel ways extending lengthwise and a tube which when placed within the exterior sections converts the channel ways into separate and distinct passages for the reception of wires.

437,469. Galvanic Battery; G. A. Liebig and C. Willms, of Baltimore, Md. Application filed June 25, 1890. This invention relates to certain improvements in electric batteries and is especially applicable to chloride of silver batteries. The object aimed at is the production of a large current cell with low internal resistance. The battery has a closed cell which is wrapped with dry cotton or other absorbent material and has a hard rubber cap

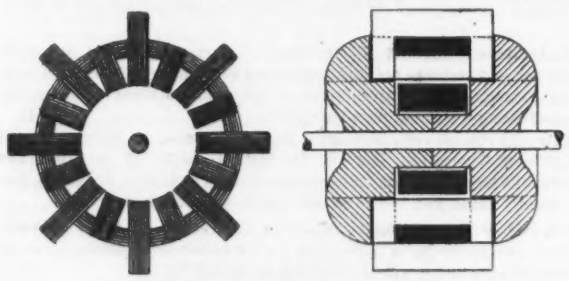


No. 437,412.—RHEOSTAT.

cemented to the glass cell and a metallic envelope incasing the whole with the corrugated chloride of silver and hollow cylindrical zinc electrodes and a solution of zinc sulphate and filtered paper, cotton or other absorbent saturated therewith.

437,501. Electric Generator; William M. Mordey, Lambeth, Eng. Application filed March 25, 1889. Patented in England, April 7, 1888; France, March 18, 1889; Belgium, March 19, 1889; Italy, March 31, 1889; Switzerland, June 25, 1889; Austria-Hungary, April 30, 1889. This invention covers a method of constructing an alternating current machine having only a single armature coil or winding, provided at opposite sides with a series of separate or independent iron masses, the masses at one side being arranged to act as magnetic inductors and placed alternately with those on the opposite side which serve as magnetic short-circuiting masses.

437,502. Arc Lamp; John A. Mosher, Abilene, Kan., Assignor of one-fourth part to Ann Mosher of same place. Application filed Dec. 31, 1889. This invention relates to an arc lamp intended for use on incandescent circuits, or to be burned on incandescent circuits either singly or in series. The invention consists of the combination with the magnets and movable cores of the carbon rod holder, the frame connected with the movable cores, the feed



No. 437,501.—ELECTRIC GENERATOR.

controlling mechanism on said frame and the dog having a tooth between its ends engaging one of the wheels of said feed controlling mechanism and having its free ends bearing on the shaft and the geared wheels.

437,510. Telegraph Key; A. F. Purdy, of Lawrence, Cal. Application filed April 15, 1890. The bed-plate of this key has side standards in combination with the key lever pivoted in the standard and a guide strip on the edges, short inner surfaces projecting beyond the inner surfaces of the standards bearing against the sides of the key lever. This construction prevents lateral motion and avoids excessive wear of the moving parts.

437,512. System of Electrical Distribution; Frank B. Rae, of Chicago, Ill., Assignor to the Detroit Electrical Works, of same place. Application filed July 13, 1888. This invention provides means whereby currents of various electromotive forces may be taken from a single generator. Converters are arranged in the main circuit for transforming portions of the main current into currents of varying electromotive force and switchboards are placed in circuit with these converters, main line telegraph circuits being connected with one of the switchboards in the circuit having comparatively high electromotive force and the local circuits being connected with switchboards having low electromotive force.

437,513. Electrical Switch; Frank B. Rae, Detroit, Mich., Assignor to the Detroit Electrical Works of same place. Application filed March 28, 1890. This switch has three independent sets of terminals and an arm carrying three independent connecting pieces arranged to make contact with the sets of terminals successively. The arm is hinged at one end and has a handle by which it is manipulated at the other.

437,516. Switchboard for Electric Lighting Systems; Robert F. Sawyer, Chicago, Ill. Application filed Dec. 11, 1889. This invention comprises a switchboard for arc light stations in which guides extend across the face of the switchboard, upon the back of which is secured spring contact terminals for the dynamo circuits. On the line of the guides and in front of openings extending through such guides are placed spring contact line circuits and short circuit terminals, and transfer plugs are provided to extend through the openings in the switchboard and to slide in the guides across the switchboards.

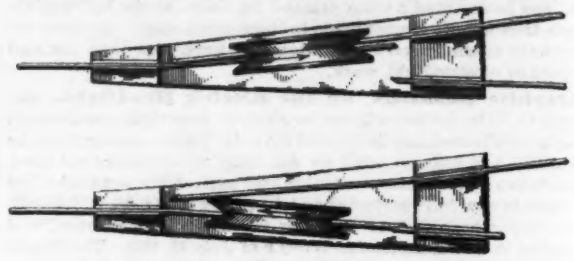
437,526. Lightning Protector for Oil Tanks; H. W. Spang, of New York, N. Y. Application filed Jan. 28, 1890. A radial system of electrical conductors is employed in combination with a delivery or supply pipe and an oil tank arranged at a considerable distance from the tank, so that the central point of lightning discharge will be in line with the radial system of conductors at a distance from the tank.

437,533. Support and Insulator for Suspended Conductors; Charles J. Van Depoele, of Lynn, Mass. Application filed April 3, 1890. This invention comprises improvements upon the insulating devices described in United States patents 393,317 and 396,312, together with other details of construction. It relates to a support for suspended bare electric conductors, comprising support sustained above the conductor and a thin metal clip formed with sloping edges and extending under the conductor and secured to the support.

437,534. Upper Pressure Contact Device for Electric Railways; C. J. Van Depoele, Lynn, Mass. Application filed April 10, 1890. The contact arm described consists of a wooden trolley pole forming a strut with metal tie rods and intermediate presses modeled upon a rock shaft and operated by a pair of springs, one of them normally acting and the other loose. The special purpose is to secure stiffness combined with ease of movement permitting the trolley to be forced down to its lowest position easily.

437,535. Motor Truck for Electric Railway Cars; Charles J. Van Depoele, of Lynn, Mass. Application filed Dec. 4, 1889. The combination that is a subject of the above patent is a secondary frame carried by the truck frame and adapted to carry a motor which is connected with one or both axles by flexible connections and sprocket chains in the drawings shown. It also contemplates track connections supported by the same secondary frame and connected to the motors.

437,568. Electric Conductor; Edward Clarke, of Newburg, N. Y. Application filed May 15, 1889. This conductor is insulated with asphalt and French mineral wool and other materials, and



No. 437,613.—TROLLEY WIRE SWITCH.

provided with an outer protecting layer of bamboo or rattan fibre with its hard outer surface outward.

437,570. Welding Metals Electrically; Charles L. Coffin, Detroit, Mich. Application filed Dec. 22, 1889. The process here patented is that of electric welding by immersing the articles to be welded in water, heating them electrically and pressing them together to form a weld by suitable apparatus.

437,571. Process of Electrically Welding Metals; Charles L. Coffin, Detroit, Mich. Application filed April 8, 1890. The electric welding process herein patented consists in bringing the parts to be welded in contact with an anvil and a conductor which is connected with one pole of a generator connecting said articles with the other poles of the generators, only passing a heating current through the articles and conductor and forming the weld while in contact with the conductor.

437,602. Ear Muffle; Ferd. P. Kaiser, St. Louis, Mo. Application filed March 17, 1890. The purpose of this invention is to facilitate receiving telephone messages by effectively stopping the ear not in use, in such a way as to avoid any possibility of injuring it. It consists of a sheet and a flange, incasing the ear, and the plug gently lying against the aperture of the ear.

437,613. Switch for the Moving Contacts of Electric Railways; John W. Murray, of Saginaw, Mich. Application filed July 15, 1890. The switch consists of a combination of the main line of the branches with oppositely pointed and spring-pressed switch-points or tongues in the manner shown in the illustration on this page.

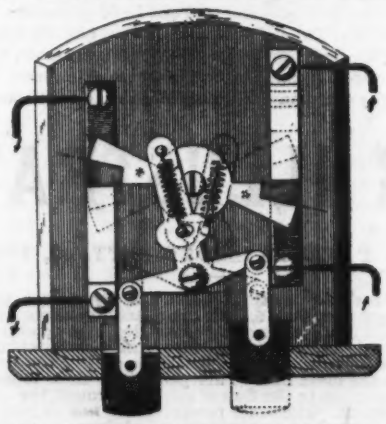
437,632. Insulated Wire; Charles F. Splitdorf, New York, N. Y. Application filed March 13, 1890. This wire is insulated by being spirally wound with flat strips of mica provided with other protecting material.

437,654. Electric Forging Apparatus; George Lauder and James H. Simpson, of Pittsburgh, Pa. Application filed July 16, 1890. The invention is designed particularly for upsetting the ends of eye bars, and consists in including a portion only of the bar or blank in an electric circuit, thereby subjecting the bar to the heating effect, applying any pressure to upset that portion of the blank, and from time to time increasing the distance between points on the bar on which the current is applied.

437,661. Motor Truck for Electrically Propelled Vehicles; Frank B. Rae, Detroit, Mich. Application filed June 13, 1889. The truck consists of a rectangular frame, rigidly mounted, of axles, cross bars connected with the frame and supporting the motor, a countershaft also connected with the frame, and the necessary gears for connecting the armature to the axle.

437,662. Automatic Switch for Stationary Motor; Frank B. Rae, Detroit, Mich. Application filed June 23, 1890. This switch is intended specially to protect stationary motors used on railway circuits, and on being operated first closes the circuit on a shunt field direct, and through a resistance in the armature circuit, which resistance is gradually and successively cut out by a movement of the switch lever so that when the switch is fully closed the circuit is direct through both the field coils, and the armature of the motor and switch is locked automatically so long as the current is within its normal limits. The operation is conducted in the reverse sense when the curve is interrupted or materially lessened by freeing the spring actuating the lever arm,

437,663. Armature for Dynamo-Electric Machines and Motors; Frank B. Rae, of Detroit, Mich. Application filed July 15, 1890. The invention relates particularly to an improved method of uniting the core and the shaft, especially when the core is laminated, and consists of a shaft having recesses in



No. 437,667.—ELECTRICAL SWITCH.

which are secured non-magnetic splines, discs having notches fitted in the splines, and the necessary end plates and nuts.

437,667. Electrical Switch; Lucius T. Stanley, of Brooklyn, and Henry B. Cutter, of Philadelphia. Application filed July 5, 1890. This invention is a double pole switch having a contact lever composed of two conducting plates with an interposed sheet of insulating material and having portions cut away at contact ends, leaving the insulation exposed so that on turning the lever the insulation is thrust between the terminals on the separation of the conducting plates from them.

437,668. Fire-Alarm Signal Box; John Young, Chicago, Ill. Application filed March 26, 1887. The apparatus is intended specially for use with an automatic fire-alarm, and consists of an attachment by means of which the truck wheel makes two revolutions and repeats its signal four times when the circuit is closed for a considerable period. In case of false alarm—that is a momentary closing of the circuit—the signal will be sent in once only, but the circuit will be left to close through the box.

Copies of the specifications and drawings complete of any of the patents mentioned in this record—or of any other patents issued since 1886—can be had for 25 cents. Give the date and number of patent desired, and address The W. J. Johnston Co., Ltd., Times Building, N. Y.